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JPRS Report

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Science & Technology

Japan

SELECTIONS FROM 1988 MITI WHITE PAPER ON INDUSTRIAL TECHNOLOGY TRENDS & ISSUES

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CONTENTS

Introduction

43067200 Tokyo SANGYO GIJUTSU NO DOKO TO KADAI in Japanese 20 Oct 88

[Excerpts]

1. It is common today to see R&D investments outstrip capital investments in major companies. The trends in research and development, and in the industrial innovation based thereon, have now come to have a large impact on the direction of industrial activity.

2. Today's industrial innovations are being developed at a speed and with a complexity never seen before. The international environment that surrounds technology and socioeconomic structures are also changing dramatically. Japan's rising economic and technological levels are having no little impact on these changes.

3. In order to best promote technological development in this broad context, in a way that is responsive to the many varied medium- and long-term problems which require technological solutions, we believe that it is of great significance to make expert and in-depth analyses and evaluations of each technological field, and based on those results, to more clearly define the directions in which industrial technological R&D should now move.

4. The Ministry of International Trade and Industry (MITI), for this purpose, and with these considerations in view, determined to [periodically] issue a publication entitled "Industrial Technology Trends & Issues" with the objective of accurately ascertaining and evaluating the trends in technological innovation and the changes occurring in the international environment. These trends and changes must be understood in order to formulate and implement MITI policies that will accord with the needs of the times.

5. The present report is the first issue of that publication. In it, the major technological innovations and breakthroughs which have been made, and the structural changes which have occurred in industry in the 40 years since the Agency of Industrial Science and Technology was formed in 1948, are examined. With the continual support of the Technology Evaluation Committee of the Industrial Science & Technology Council, each technological field was expertly and scientifically analyzed and evaluated in depth, from the

following four perspectives, focusing on periods of time appropriate to each issue.

(1) A time-oriented awareness of today's technological innovations as seen in the flow of history

(2) An accurate understanding of Japan's own technological levels and R&D programs, and the state of international technological exchange

(3) Trends at the leading edge of R&D in industrial technologies

(4) An evaluation of Japanese industrial technology, as informed by the above perspectives, and a clear enunciation of problems and tasks for the future

Based on the informative results of these analyses and evaluations, we have clearly set forth below the industrial technological tasks which must be undertaken, and the policies which must be pursued, as Japan moves toward the 21st century.

6. These findings may be summarized as follows:

(1) As we approach the next century, what is most urgently needed as the driving force to resolve such global issues as food, natural resources, energy, and environment, and to promote further social and economic advancement around the world, is what we are calling a "technological revolution to carry us through the 21st century." This technological revolution must produce one new technology after another, based on the brand new scientific discoveries and inventions which are currently being made.

(2) In this context, we are now beginning to see hopeful signs of technological innovations which harbor within themselves the possibility of exerting very far-reaching effects. These signs have recently become visible in such fields as new materials, electronics, and biotechnology. And, as the phenomenon of the convergence of and resonance between science and technology becomes increasingly evident, we are beginning to see more clearly that R&D tasks must be undertaken, and what directions to push research in, in order to nurture and bring to fruition the budding new technological innovations and revolutions.

(3) Japanese industrial technology has developed rapidly in the postwar era with a primary focus on applications R&D. This has placed Japanese technology at the top level in the world in many fields.

(4) As Japan's economic power and the level of its industrial technology have risen, it has become necessary for Japan to play an increasingly large role in basic technological fields as well as in the application-oriented and developmental areas of industrial technology. World expectations regarding this expanded role for Japan--so necessary to the harmonious development of the world economy and to the wholesome development of science and technology--have also intensified.

(5) In this context, it is evident that Japanese industrial technology is now at a critical turning point which demands the bolstering of basic and creative research as well as strenuous efforts to contribute more to the international community.

Moreover, the most important task now facing Japan in the realm of industrial technological research and development is to take the lead in meeting the challenge of achieving the "technological revolution needed to carry us through the 21st century." To do this we must engage in research that is focused on what is fundamentally and essentially basic research. In the course of these endeavors, and making the best use of the results and spin-off effects arising therefrom, we must make more strenuous efforts to contribute to the global community.

(6) Succinctly stated, these perspectives may be summarized as "taking the initiative in meeting the challenge of the technological revolution needed to carry us through the 21st century, and contributing to the international community."

Chapter 2. Trends in Japanese Industrial Technology

(1) As we saw in the discussion in Chapter 1 on the historical development of industrial technology in the world, Japanese industrial technology got off to a new start after the war, and has been growing and developing ever since.

(2) In Section 1 of this chapter, we analyze the current status of Japanese industrial technology, focusing on the following three areas:

A. Technology level and technological development potential, by industry, product, and technology

B. R&D base, in terms of R&D funding, human resources, and supporting infrastructure

C. Technology transfer and international exchange of researchers and technological information

(3) Then, in Section 2, we analyze the trends in basic research and development and the R&D trends in the private sector. In so doing, we examine the changes occurring in the nature of the R&D work now being done at the leading edge of industrial technological R&D in Japan, and look at how developmental trends are changing also.

Section 1. Current Status of Japanese Industrial Technology

Subsection 1. Level of Japanese Industrial Technology

(1) In order to analyze the current status of Japanese industrial technology, it is imperative that we analyze the levels of the various industrial technologies in order to understand the position and role of Japanese industrial technology in the world community.

(2) The analysis of technology levels will be based primarily on objectively and accurately apprehending those levels. In conducting such an analysis, we must be very conscious of how varied these levels will be, depending on the industry, the product, the technologies involved, and the relative stage of the technology (i.e., basic research, applications research, further development, etc.).

(3) We can also comprehend the effective means and factors which enhanced the technology levels and developmental potential by carefully analyzing the underlying factors which led to the various changes in the technology level.

(4) In achieving the objectives stated above, we must also examine the underlying elements and promotional factors which led to the current (enhanced) level of each industrial technology. To facilitate this, we have examined a total of 134 products or technologies at various stages, including "conventional products," "high-tech products," and "basic technology."

Note 1: The terms "technology level," "technologies development potential," "conventional products," "high-tech products," and "basic technology," as used herein, may be defined or restricted as follows:

Technology level: Determined after comprehensively considering the performance level and reliability of each product, and the level of the technology which is embodied in the product

Technological development potential: The ability to raise the technology level; the degree of latent developmental potential which the technology inherently possesses in terms of overcoming existing problems and with respect to the development of new technology in the future

Research level: Scientific or technological opinion in the research field, or cumulative technological rating

Conventional products: Representative products of industry groups which have already played a fundamental role in Japan's industrial technologies development, and currently play a major role in forming the industrial and societal structure of Japan (47 products; cf Figure 2-1-1-1)

High-tech products: Products which require a high degree of advanced technology, which currently form or are expected in the future to form a large market, and which had reached the product or pre-product stage 5 years ago (40 products; cf Figure 2-1-1-4)

Basic technology: Field of technology which is still at the level of basic research, which is expected to exhibit significant development and practical implementation at the end of this century and into the next, and which is expected to support the 21st century (47 fields; cf Figure 2-1-1-9)

Note 2: In analyzing and studying the "technology levels" and technological development potential," we sent questionnaires to 1,953 companies in the private sector (receiving valid responses from 980 companies) and to national testing and research institutions (212 researchers in 16 institutions), and conducted hearings with specialists. The results of these surveys were examined, commented on, and evaluated for accuracy by a wide range of specialists, scientists, and field personnel (cf Summary of Questionnaire Survey Results in the Appendices at the end of this volume)

(5) When we examine the results of evaluating the overall levels of Japanese industrial technology as discussed above, it is clear that high levels have been reached in conventional products, high-tech products, and basic technology (in descending order). In a considerable number of conventional and high-tech product technologies, moreover, we have either approached or reached the top levels in the world.

These high levels in conventional and high-tech product technologies could not have been achieved without the support of basic technology. In that sense, we may be sure that basic technology has also reached a considerable level in Japan. When we look at the level of the research being done in the most advanced fields (the kind of fields that will support 21st century industry), there are indeed a considerable number of individual elemental technologies where we are at the highest levels in the world. In overall terms, however, we are still behind in a large number of technologies.

We now proceed to examine the results of the technology level evaluations in the three areas of conventional products, high-tech products, and basic technology.

1. Conventional Product Technology Level

(1) Technology Level

<1> Looking at the changes in the technology level for conventional products, Japan was already at or near the top levels in many products. These levels have risen even higher in the past 10 years, particularly in the processing and assembling industries (cf Figure 2-1-1-2).

<2> When we look more carefully at each product, there are some industries, such as the machine tool field, in which we are one of the overall leaders in the world. In such technological fields as high-precision machining, high-speed processing, or special materials processing, however, we are still not quite up to the top levels in the world. In the field of business equipment, Japanese industry is a world leader in terms of the overall level of equipment technology, but in areas like software technology we lag behind. This makes it difficult to evaluate the overall technology level. In certain fields such as pharmaceuticals and agricultural chemicals, where there has not been an adequate build-up of basic technology, the technology level is still low.

<3> Japan has been active in the NIEs (newly industrialized nations), where the expansion of Japanese industry has brought with it technology transfers and technology acquisitions by local companies, and has promoted autonomous technological development. In certain fields such as watches, fertilizers, and synthetic fibers, the technology levels in these nations have become much closer to ours in the past several years. In no case, however, has the technology level in these nations surpassed the Japanese level.

(2) Technological Development Potential

Turning our attention next to technological development potential, this has risen in like manner as have technology levels, and in many fields we are at or near a position of world leadership. The level is notably low in such fields as pharmaceuticals and agricultural chemicals (cf Figure 2-1-1-2).

(3) Background of Rising Technology Levels and Technological Development Potential

When we examine the factors underlying the advances in technology level and technological development potential discussed above, we find that improved production technology and automation of manufacturing processes have been large factors in the basic materials industries. In the processing and assembling industries, the more extensive use of electronics technology has been a major factor in addition to manufacturing process automation and production technology advances (cf Figure 2-1-1-3).

Another background factor is the oil crisis, together with the changes in the energy price structure which it brought about. In order to develop new business opportunities in the face of this crisis, a great amount of intense R&D work was done in the private sector in the interest of cutting energy consumption and developing higher value-added production technologies.

As advances were made in electronics technology, microcomputers came to be built into equipment and process facilities. This facilitated diversified small-lot production, lower consumption of natural resources, and energy, greater product quality uniformity, and an accelerated advance toward more sophisticated production technology.

In order to implement the results of R&D at the actual production site, productivity was improved by standardization, and more thoroughgoing quality control was instituted through TQC (total quality control) and QC circles. We must not overlook the contributions which such unflagging diligence in the area of production management has made in raising technology levels in Japanese industry.

Industry	Product classification
(1) Basic Materials Industries	
1) Steel industry	1. Ordinary steel
2) Chemical industry	2. Synthetic fibers
	3. Synthetic resins
	4. Fertilizers
	5. Industrial chemicals (organic intermediates, etc.)
	6. Synthetic rubber
	7. Dyes and pigments
	8. Surfactants
	9. Pharmaceuticals
	10. Agricultural chemicals
	11. Films
3) Other basic materials industries	12. Girders, beams, steel frames, tanks (steel reinforced)
	13. Aluminum products
	14. Aluminum refining
	15. Electrical wire and cable
	16. Petroleum refining
	17. Tires
	18. Glass
	19. Cement
(2) Processing and Assembling Industries	
1) General machinery industry	20. Engines and boilers
	21. Machine tools
	22. Environmental machinery
	23. Construction machinery
	24. Air/water-power machinery
	25. Plants (steel refining, chemical, petroleum refining plants, etc.)
	26. Machine parts (seal material, valves, bearings, pistons, etc.)
2) Electrical machinery industry	27. Nuclear power-generating equipment
	28. Conventional power-generating equipment
	29. Industrial electrical equipment
	30. General-purpose electrical equipment
	31. Audio/video equipment
	32. Electrical appliances (refrigerators, washing machines, etc.)
	33. Medical equipment
3) Automotive industry	34. Automobiles
	35. Trucks

Figure 2-1-1-1 Conventional Products Considered (47 products)

[figure continued]

[Continuation of Figure 2-1-1-1]

Industry	Product classification
4) Other machinery industries	36. Ordinary cargo ships 37. Special cargo ships 38. Railroad rolling stock and railroad systems 39. Cameras 40. Watches 41. Measuring instruments 42. Business equipment
(3) Consumer Related Industries	
1) Textile industry	43. Natural fibers
2) Other consumer related industries	44. Food
(4) Mining industry	45. Oil and natural gas production
(5) Construction industry	46. Construction 47. Civil engineering

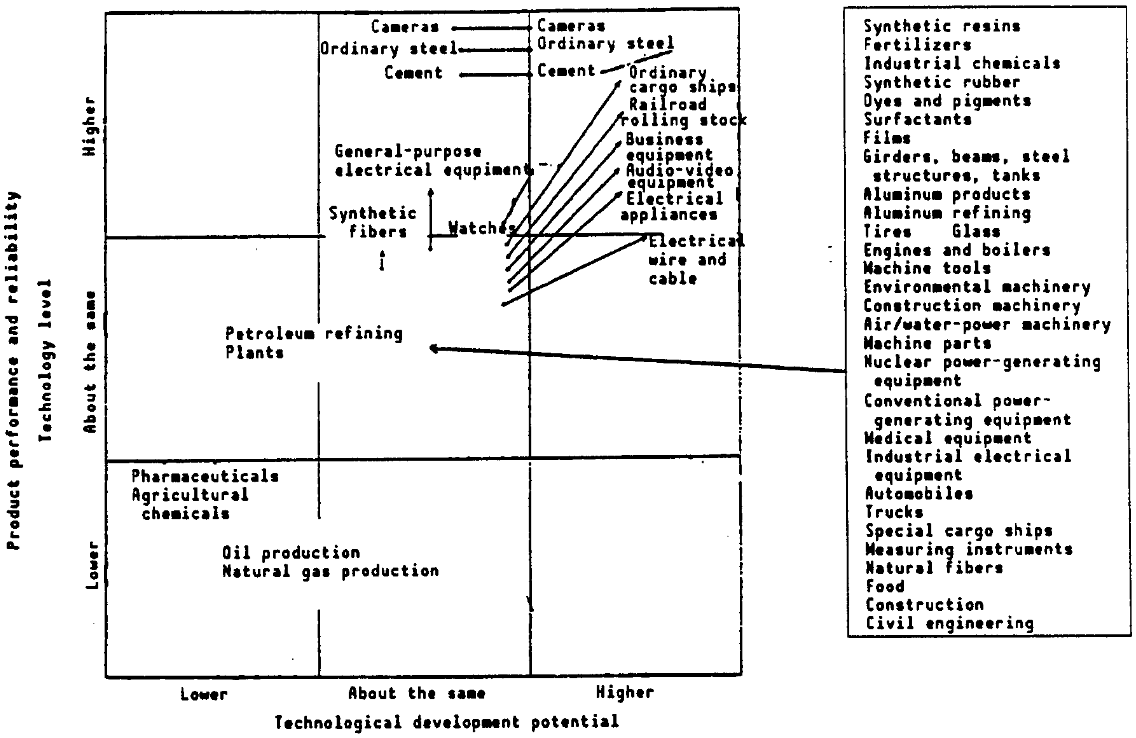

Figure 2-1-1-2 Technology Levels, Development Potential in Japan in Conventional Products--Changes over 10-year period

Notes: 1. Levels for each product represent 10-years previous and current Japanese levels compared to European/American levels.
2. Origin of arrows represents level 10 years ago; terminus represents current level.
3. The levels for technological development potential are indicated in terms of developmental potential in research and development.
4. The relative position of a product or industry within a box has no bearing on its relative level.

Source: Produced from results of a survey conducted by the Agency of Industrial Science and Technology

Basic Materials Industries

Steel Industry:

Product	Factors underlying change
Ordinary steel	• Introduction of largest blast furnaces, advances in production technology (continuous casting technology, refining technology, etc.) • Intensified R&D endeavor in fields like new materials

Other Basic Materials Industries:

Product	Factors underlying change
Electrical cable	• Expanded R&D endeavor due to increased demand for electricity • Intensified R&D work in new materials field
Cement	• Automation of production processes • Intensified R&D work in new materials field

Processing and Assembling Industries

Electrical Machinery Industry:

Product	Factors underlying change
General-purpose electrical machinery	• Automation and rationalization of production processes • Wider use of electronics technology
Audio and video equipment	• Wider use of electronics technology • Automation of production processes, demand diversification
Home appliances (refrigerators, washing machines)	• Demand diversification (increased demand for more highly functional products) • Wider use of electronics and new-materials technologies

Other Machinery Industries

Product	Factors underlying change
Cargo ships (freighters, tankers)	• Automation of production processes, enhanced reliability due to automation of operations • Wider use of new-materials technology
RR rolling stock and railroad systems	• Increased demand for greater transportation capabilities • Wider use of electronics technology
Cameras	• Wider use of electronics technology • Intensified competition (domestic, NIEs)
Watches	• Wider use of electronics technology • Automation of production processes
Business equipment	• Wider use of electronics technology • Automation of production processes (CAD/CAM, factory automation implementation)

Figure 2-1-1-3 Factors Underlying Changes in Technology Levels and Technological Development Potential for Conventional Products

2. Technology Levels for High-Tech Products

(1) Technology Levels for High-Tech Products

<1> The technology levels for high-tech products have risen for a considerable number of products, as was true for the conventional products as we saw in Section 1. Japan is now at or near the top level in the world in quite a number of these products (cf Figure 2-1-1-5).

Among the 40 high-tech products surveyed, a large improvement in technology level was achieved over the 5-year period in the following products:

Technology Field	Product
New materials	Composite materials
	Amorphous alloys
	Macromolecule separation films
	Fine ceramics
Electronics	Semiconductor memory elements
	CCDs (charge-coupled devices)
Information, communications	Computers
	D-PBXs (digital PBXs)
	Laser printers
Processing, machining, manufacturing	Laser machining equipment
	CAD/CAM
	Hydraulic pressure regulating valves
Analysis, measurement equipment	Accelerators
	Spectrum analyzers
Biotechnology	Bioproducts using animal cells
	Bioproducts using microbes
Aerospace	Communications satellites
Large structures	Super-high-rise buildings

<2> As may be seen from the foregoing, there has been a large rise in technology levels during these 5 years more than 40 percent of the 40 surveyed products. As a result, the technology level for high-tech products has reached a high overall level, with no bias toward any particular technological field or processing stage (such as basic materials, parts, or finished goods) seen when examined by product category.

<3> This rise in technology levels resulted in the following developments.

A) Five years ago, Japan had achieved the top level in only about 10 percent of the high-tech products surveyed, including high-tensile-strength steel, home VCRs, and solar energy. During the 5-year period, however, the level rose in fine ceramics, spectrum analysis, and other fields, so that Japan is at the top level today in more than 20 percent of the products surveyed.

Table 2-1-1-4 High-Tech Products Surveyed

A. Materials

1. High-tensile strength steel
2. Amorphous alloys
3. Superconductors (at temperature of liquid helium)
4. Fine ceramics
5. New glass
6. Macromolecule separation films
7. Engineering plastics
8. Composite materials

B. Parts

9. Optical fiber
10. Semiconductor lasers
11. CCD
12. Semiconductor memory elements
13. Microcomputers
14. Bore screws
15. Servo motors
16. Hydraulic pressure regulating valves

C. Finished Goods and Systems

17. Optical-magnetic disks
18. 1/2-inch home VCRs
19. Computers
20. Databases
21. CAD/CAM
22. Copiers
23. D-PBXs
24. Assembly robots
25. Laser machining equipment
26. Laser printers
27. Accelerators
28. Spectrum analyzers
29. Aircraft engines
30. MRI
31. Artificial kidneys
32. Bioproducts using animal cells
33. Bioproducts in botanical field
34. Bioproducts using microbes
35. Light water reactors
36. Solar energy
37. Satellite launch rockets
38. Communications satellites
39. Seagoing structures
40. Super-high-rise buildings

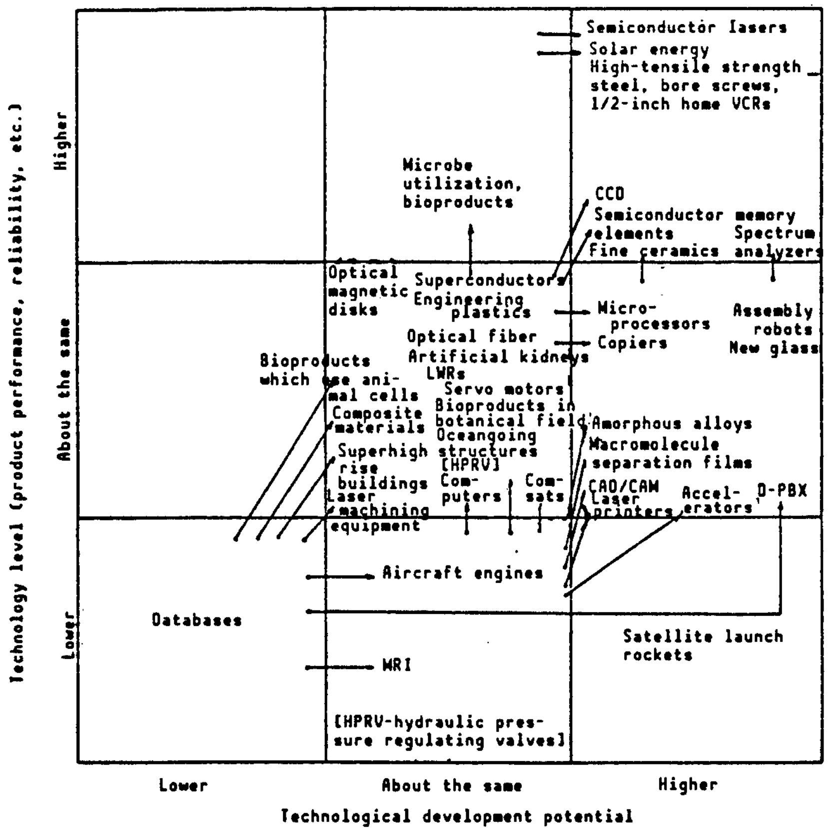

Figure 2-1-1-5 5-Year Change in Japanese Technology Levels and Technological Development Potential for High-Tech Products

Notes:

1. Levels for each product represent 5-years previous and current Japanese levels compared to U.S. levels.
2. Origin of arrows represents level 5-years go; terminus represents current level.
3. The absence of an arrow indicates no change.
4. The levels for technological development potential are indicated in terms of developmental potential in (improvement-oriented) research and development. In applications and basic research, general comparisons were made with developmental research, and the lower level taken.
5. The relative position of a product or industry within a box has no bearing on its relative level.

Source: Survey conducted by the Agency of Industrial Science and Technology (March 1988)

B) Five years ago, Japan had failed to reach the top level in more than 40 percent of the high-tech products, including amorphous alloys, macromolecule separation filters, computers, and CAD/CAM. This ratio is now down to about 10 percent.

C) As a result of the foregoing, Japan is now at or near the top level in the world in about 90 percent of the high-tech products.

<4> However, in product categories which demand general systems technologies, such as aircraft engines, MRI (magnetic resonance imaging), and databases, and in categories in which Japan has been doing developmental work for a relatively short time, Japan has not caught up with the world leaders. This is not true for some component and element technologies, but it is true in terms of overall systems.

(2) Technological Development Potential for High-Tech Products

<1> As was the case with technology levels, the technological development potential has generally risen over the past 5 years for high-tech products. In particular, Japan is at or near the top level in the developmental research stages (cf Figure 2-1-1-5).

<2> Japanese prowess in technological development potential in the developmental research stages has been highly regarded internationally for some time. Five years ago, Japan was at or near the top level in roughly 80 percent of high-tech products. Thanks to further rises in developmental potential since then, however, there are currently very few areas (such as databases) where Japan has not become a world leader.

(3) Background of Rising Technology Levels and Technological Development Potential

<1> The technology levels and technological development potential in Japan in the area of high-tech products have been steadily rising. Some of the factors which promoted this rise are listed in Figure 2-1-1-6.

<2> We will now classify these promotional factors, dividing them first between market-based factors and technology-based factors (cf Figure 2-1-1-7).

A) Market-Based Promotional Factors

a. Expectation of Market Growth

Amorphous alloys and fine ceramics constitute product categories for which a large market was expected to develop in the future. Intense competition developed, with many companies in a wide range of businesses seeking to expand their business into these product areas through joint research and technology acquisition. As a result, dramatic advances were made in technological development potential, and technology levels rose rapidly.

b. **Demand Growth**

The demand for accelerators and MRI equipment in the medical field has grown in recent years. User demand resulted in improved product quality and a rise in the technology level.

c. **Competition in International Markets**

Rises in the technology level in CAD/CAM, copies, and D-PBXs (digital PBXs) are attributable to the technological efforts made to cope with the existence of strongly competitive companies overseas, and to severe quality demands in both domestic and foreign markets.

B) Technology-Based Promotional Factors

a. **Spin-Off From Related Technologies**

The technology level has risen in almost all technological fields, in terms of both equipment and systems, due to the advances made in product component technologies and production technology. Examples of this are seen in the electronics components found in copiers and laser printers, the computers used in MRI systems, and the ultramicroscopic techniques used in making semiconductor memory devices. In particular, the high level of Japanese electronics technology is playing a wide range of high-tech product fields.

b. **Heightened Intensity in Technological Development, Basic Research**

As is evident in the microprocessor field, there has been a growing trend, especially in the larger companies, to give higher priority to technological development and basic research. This has led to increased investment in research and development and the acquisition of highly talented research personnel. The result has been a gradual rise in the overall technology level and technological development potential.

c. **Tighter Quality Control**

In addition to improved production technology, the excellence of the factory labor force and the outstanding quality control programs in Japan have played very important roles in raising industrial technology levels. This is seen particularly in the fields of semiconductor memory devices and computers.

d. **Stimulating Effects of National R&D Projects**

National R&D projects--such as those involving laser machining equipment, solar energy, macromolecule separation films, and bioproducts using animal cells--have stimulated and induced R&D activities in the private sector. These projects have played a pump-priming role in promoting technological development in these fields. This intensification of private research and development has helped to raise technology levels and technological development potential overall.

Category	Product name	Factors underlying change in technology level
Materials	Amorphous alloys	(1) Severe developmental competition arose as home appliance makers joined metal materials makers to manufacture magnetic heads (a typical application), which raised the technology level and the technological development potential. (2) With respect to transformer applications, the United States leads in durability evaluating technology.
	Fine ceramics	(1) Since the early 1980's, many industries (including chemicals, textiles, steel, nonferrous metals, machines, and engineering [plastics]) have been attracted by the good prospects for fine ceramics and have moved into the field. This has intensified R&D efforts and raised the technology level. (2) When newly moving into the field, a company usually engaged in joint research with a university. This, together with the adoption of "next-generation" systems, helped raise the technology level.
	Macromolecule separation films	(1) In fields where user demands were severe, such as in manufacturing super-pure water, prodigious R&D efforts resulted in a higher technology standard. (2) Tasks for the future include the improvement of separation capabilities and durability for saltwater purification and gas separation.
	Composite materials (containing carbon fiber)	(1) Aerospace users required strict specifi cations for carbon fiber, resulting in prodigious R&D efforts and a higher technology level. (2) The adoption of "next-generation" programs also contributed to higher technological development potential.
Parts, components	Semiconductor lasers	(1) The use of these lasers as components in such fiercely competitive products as CDs and videos was a factor in raising the technology levels. Much developmental work focused on noise reduction.

Figure 2-1-1-6 Factors Underlying Changes in Technology Levels and Technological Development Potential for High-Tech Products

[figure continued]

[Continuation of Figure 2-1-1-6]

Category	Product	Factors underlying change in technology level
		(2) Data processing and communications applications required higher outputs and greater stability, resulting in high technology level in area of product development.
	CCD (charge-coupled device)	(1) The miniaturizing technology developed in LSI manufacture contributed to increasing the number of pixels, and thoroughgoing quality control was implemented. As a result, this product can now be used in place of conventional picture tubes. (2) This enhancement of production technology resulted in a higher technology level.
	Semiconductor memory elements	(1) Miniaturization technology was critical in achieving larger capacities and higher integration. (2) This led to rapid advances in exposure devices, photosensitive materials, and etching techniques which, together with Japan's outstanding labor force, resulted in a high technology level in manufacturing.
	Microprocessors	(1) As the importance of new architectures increased in the course of miniaturization advances, tremendous in-house design efforts were made, and the copyright problems of recent years became a serious focus. This led to higher in-house development potential. (2) In the area of technology levels, the United States has a great historical advantage.
	Hydraulic pressure regulating valves	(1) Advanced electronics technology has contributed to higher technology levels in highly controllable hydraulic pressure regulating valves. (2) Europe is slightly ahead in high-pressure regulating valves.
Finished goods and systems	Computers	(1) Superior quality control contributes to higher levels in software as well as hardware design. (2) Spin-off from large national projects has been a contributory factor. (3) In terms of innovative software creation, the United States is far ahead.

[figure continued]

[Continuation of Figure 2-1-1-6]

Category	Product name	Factors underlying change in technology level
	CAD/CAM	(1) Rapid CAD/CAM proliferation in machine industries, and the development of small, easy-to-use systems, has raised the technology level, as well as the technological development potential in the area of product improvement. (2) The United States continues to dominate in producing new software and other creative research.
	Copiers	(1) Expanding export markets increased demands for quality stabilization and greater reliability. The technological advances in production technology in response to these demands have raised technological development potential. (2) Technology level rose due to advances in basic technologies such as photosensitive materials and development techniques, and to multifunctionality resulting from use of electrical/electronic components such as microprocessors and sensors.
	D-PBX (digital PBX)	(1) Efforts to improve functionality in response to sophisticated demands of U.S. users contributed to higher technological development potential. (2) High level of electronic component technology helped raise hardware level.
	Laser machining equipment	(1) Promoted by the large project called "Complex Production Systems Using Super-High-Performance Lasers" (1977-1984), research moved ahead on laser generators, optical systems, and control systems. This resulted in higher technology levels and greater technological development potential. (2) R&D work on the laser generation mechanism itself is concentrated in Europe.
	Laser printers	(1) The technology level and technological development potential have risen rapidly in small and medium-sized units due to improved photosensitive materials in electronic photography systems, improved toner quality, and the employment of semiconductor lasers in text writing systems.

[figure continued]

[Continuation of Figure 2-1-1-6]

Category	Product name	Factors underlying change in technology level
		(2) In the larger units, the United States leads in optical technology for achieving wider printer widths.
	Accelerators	(1) Demand has grown in the medical and industrial fields in addition to conventional analysis applications. This has advanced R&D and raised technological development potential. (2) High level of computer technology used in electron beam measurement systems has helped raise the overall technology level in the accelerator field.
	Spectrum analyzers	(1) Development efforts were focused on reducing IC noise levels and broadening bandwidths. (2) In-house development of more of the critical components in transmitters and filters, etc., contributed to higher technological development potential.
	Aircraft engines	(1) Through U.S. aircraft engine licenses and participation in large national projects, technological development potential has been gradually rising. (2) The V2500 engine has been under international joint development since 1979. If the V2500 becomes a viable engine, this should dramatically raise the technology level.
	MRI (magnetic resonance imaging equipment)	(1) Japan is behind the United States in strong magnetic field MRI using superconductor technology. In medium magnetic field MRI using ordinary conductors and permanent magnets, however, Japanese industry has achieved compactness, high performance, and lower prices through the use of high-level computer technology in image and data processing and innovations in magnetic shielding. (2) More recently, Japanese companies are also able to produce superconducting MRI systems, and the technological development potential in this field is gradually rising.

[figure continued]

[Continuation of Figure 2-1-1-6]

Category	Product name	Factors underlying change in technology level
	Bioproducts (using animal cells, microbes)	(1) Products tend to be directly linked to basic research, and companies are more aware of how critical basic research is. This is leading to a higher technology level. (2) Bio research is now a part of "next-generation" programs. This has a pump-priming effect in intensifying private-sector research. (3) U.S. basic research is at a high level thanks to heavy funding by NIH, etc.
	Solar energy	(1) Solar energy research in Sunshine Project has contributed to higher technological development potential. (2) Many home appliance makers have moved into solar battery field, helping to raise overall technology level. (3) Technological environment has deteriorated in United States due to market shrinkage and researcher shortages.
	Communications satellites	(1) Research on and experience with comsats over past 20 years has resulted in: (a) use of domestic relay units in CS-2 in 1983, which raised international perceptions of Japanese communication satellites technology; (b) 80 percent + use of domestic components in CS-3 in 1987, and higher-powered implementation; (c) As a result, the technology level rose.

Note: "Next-generation" programs refer to the "R&D System for Next-Generation Industries" (also called "Next-Generation System"), promoted by the Agency of Industrial Science and Technology since 1981.

[Under each major division, the underlying factor classification is followed by specific examples of product names and specific promotional factor(s).]

Market-Based Factors

Intensified Competition

Amorphous alloys	• Entry into field by home appliance makers
Fine ceramics	• Entry into field by various industries
Semiconductor lasers	• Stiff competition in consumer applications

More Sophisticated User Demands

Macromolecule separation films	• Sophisticated demands for superpure water manufacturing
Composite materials	• Sophisticated aerospace demands
CAD/CAM	• Demand for smaller, easier-to-use systems
Copiers	• Higher quality demanded in overseas markets
D-PBX	• Higher quality demanded in overseas markets

Demand Growth

Accelerators	• Growing demand for medical, industrial uses
MRI	• Growing demand for medical applications

Technology-Based Factors

Spin-off From Related Technological Fields

Copiers	• Spin-off from electronics technology
D-PBX	• Spin-off from electronics technology
Spectrum analyzers	• Spin-off from electronics technology
Laser printers	• Improved photosensitive materials and other chemical materials • Spin-off from electronics technology
Computers	• Improved hardware
Accelerators	• Spin-off from computer technology
MRI	• Spin-off from computer technology
CCD	• Improved microprocessing technology
Semiconductor memories	• Improved microprocessing technology
Solar energy	• Spin-off from consumer-oriented solar battery technology

Figure 2-1-1-7 Factors Underlying Changes in Technology Levels and Technological Development Potential for High-Tech Products

[figure continued]

[Continuation of Figure 2-1-1-7]

Greater Zeal in In-House Development Basic Research	
Microprocessors	• Stronger trend toward in-house design • Intensification of copyright problems
Spectrum analyzers	• Greater use of in-house developed components
Bioproducts (using animal cells, microbes)	• Higher company priority on basic research
Super-high-rise buildings	• Development of exclusive technology to cope with earthquakes, etc.

Stimulation, Spin-Off From National Projects	
Laser machining equipment	• Spin-off from large projects
Computers	• Spin-off from large projects
Bioproducts (using animal cells, microbes)	• Spin-off from Next-Generation System
Fine ceramics	• Same as above
Macromolecule separation films	• Same as above
Composite materials	• Same as above
Solar energy	• Spin-off from "Sunshine Project"
Aircraft engines	• Spin-off from "V2500 International Joint Project," other large projects

Other Technology-Based Factors	
Semiconductor memories	• High quality of factor labor force
Computers	• Thoroughgoing quality control programs
Aircraft engines	• Technology accumulation through licensed production
Communications satellites	• Long-term technology accumulation
Super-high-rise buildings	• Long-term technology accumulation

C) Dependence on Overseas Technology

When we study the factor of technological originality which underlies high-tech products, and examine how dependent Japanese industry is on foreign as opposed to Japanese inventors for its patents and know-how, we find that, with the exception of certain high-tech products, the foreign dependence is between 20 and 30 percent or so. We may infer from this that [much] related technological development is being done in-house, in some fashion or other (cf Figure 2-1-1-8).

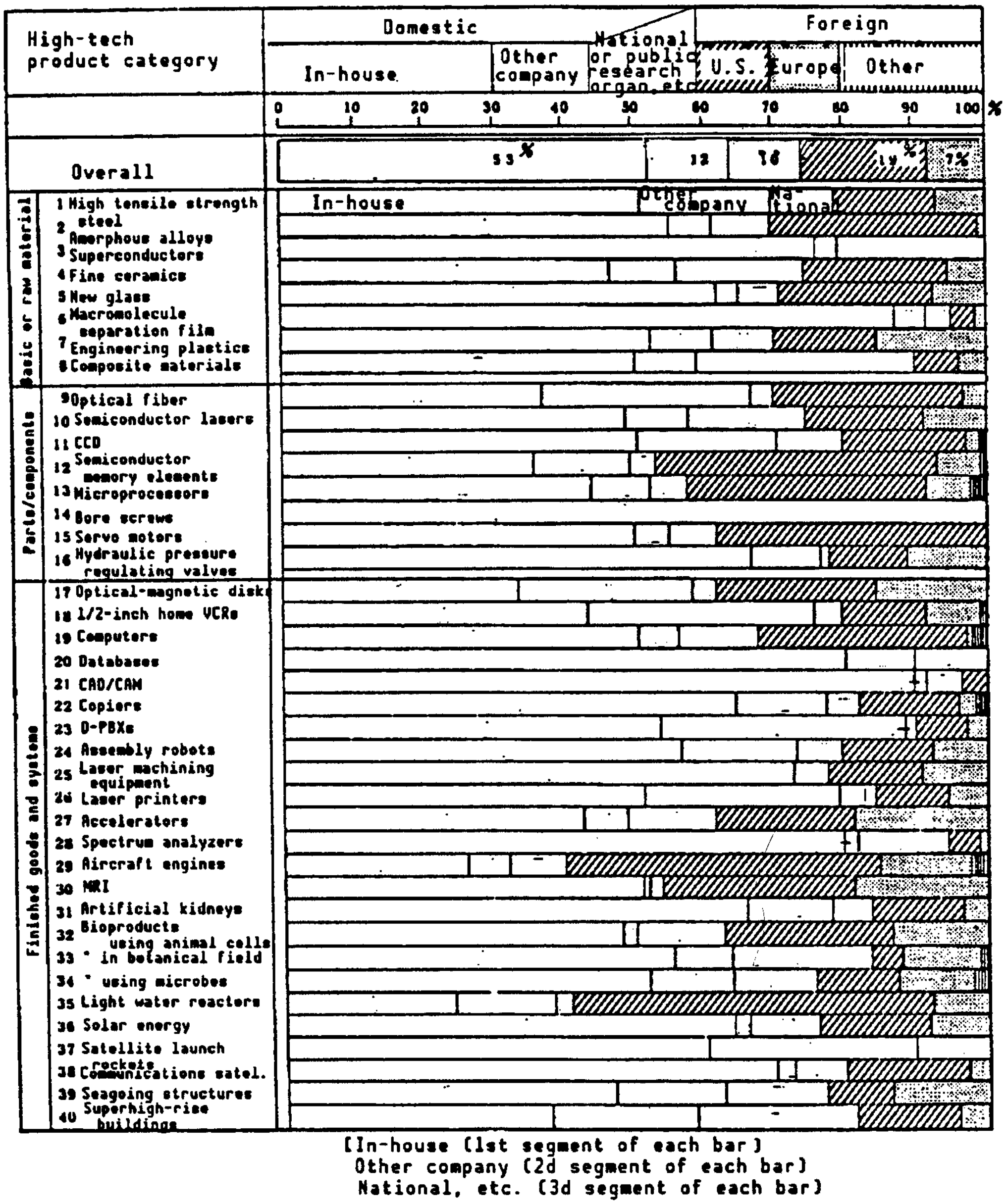

Figure 2-1-1-8 Dependence on Domestic/Foreign Patents and Know-How for High-Tech Products (Dependency factor*)

Note: * The dependency factor is a measure arrived at by first classifying patents and know-how (that are actually used employed n designing, producing, or using a product) by "inventor," and then quantifying the degree to which the respective "inventors" contributed to the said design, production, or use. In making the quantification, overall consideration is given to the quantitative and qualitative contributions of the patents and know-how.

Source: Survey conducted by Agency of Industrial Science and Technology

(Cf summary of each of these 47 fields at end of volume)

New Materials

1. High-temperature superconductors
2. Nonlinear photoelectronic materials
3. Ferromagnetic materials
4. Molecular function materials
5. Super-environment-resistant advanced composite materials
6. New alloys, intermetallic compounds
7. New-function fine ceramics
8. New-function carbon-based materials
9. New-function glasslike (noncrystalline) materials
10. High-purity precision macromolecular materials
11. Silicon chemical materials
12. New microelectronic materials

Electronics

1. Superconductor devices
2. Quantified functional elements
3. Power electronics elements
4. New optical functional elements
5. Large-area circuit elements

Biotechnology

1. Functional enzymes, creation of biological substances
2. Animal- and plant-cell engineering
3. New genetic engineering
4. Bio-databank formation
5. Search for and classification of microbes, plants, and animals that will constitute new genetic resources
6. Technology for sophisticated utilization of biological reactions

Technologies Related to Both New Materials and Electronics

1. Precision atomic control technology
2. New processes for creating metallic and inorganic materials
3. Precision atomic arrangement control technology
4. Evaluation, analysis, and measurement technologies
5. Design and simulation technologies
6. Optical reaction process technology
7. Extreme environment creation technology

Figure 2-1-1-9 Basic Technology Fields Surveyed

[figure continued]

[Continuation of Figure 2-1-1-9]

Technologies Related to Both Electronics and Biotechnology

1. Protein handling (arranging) technology
2. Biomembrane utilization technology
3. Development of biorelated analysis and evaluation systems

Technologies Related to Both New Materials and Biotechnology

1. Life-function modeling technology
2. Organism adaptability technology
3. Biochemical utilization technology
4. Bioprocess separation and refining technology

Software, Systemization

1. Self-managing information processing mechanisms
2. Data processing mechanisms of the automatic nervous system
3. Super-parallel architectures
4. Managing software for machine control systems
5. Software harmonization and development technology
6. Disaster early-warning technology
7. Environmental control technology
8. Human technology
9. Natural resources and energy technology
10. Functional robot technology

3. Research Levels in Basic Technology Fields

(1) Current Research Levels

A) It is believed that the technology level and technological development potential in the high-tech products discussed above have been achieved because of the support provided by accumulated basic research. We evaluated Japanese research levels in basic technology areas in the most advanced research fields (47 fields surveyed) that will be critical in the 21st century (cf Figure 2-1-1-10). This evaluation was based in research findings publicized to date. There are problems with making static evaluations of research levels at a given point in time, however, and this reservation should be kept in mind when examining R&D activities which are marked by very short-term gains.

B) Consequently, Japanese research may be viewed as being at or near the top levels in the world in certain areas of such fields as ferromagnetic substances, high-temperature superconductors, new function materials, superconductor devices, new materials, and electronics.

C) In other basic technology fields, although Japanese research is at high levels with respect to some specific element technologies, when it comes to research in discovering and elucidating phenomena or mechanisms, the level in Japan is not very high. In research support fields such as bio databanks, techniques for evaluating, analyzing, and measuring, and extreme environment creation, moreover, the level of Japanese research is low compared to other fields.

(2) **Research Level Background**

A) Japan has a long history of research in such technological fields as ferromagnetic substances, high-temperature superconductors, and superconductor devices, where it has achieved levels near the top in the world. From this we may infer that Japanese research levels have been raised by accumulated research successes and technological know-how in a wide range of related technological fields, and by the high levels achieved in such elemental technologies as improving material compositions, processing and integration. The level of research being done in such purely scientific areas as elucidating theoretical mechanisms, however, is currently not very high.

B) When we examine the reasons for the gap between Japan and the United States in fields where Japanese research lags behind the top levels, we may cite the disparities in the respective climates or environments in which scientific research is done and in the respective quantities of research done to date. The United States, in other words, supported by high levels of capability in analysis and evaluation, can utilize its broadly based research potential in such theoretical areas as the elucidation of new phenomena and new functions. In addition, there is the vast accumulation of technology and know-how which has resulted from the large-scale, broad-based, and government-subsidized research in aerospace and other defense fields. The United States also has a wealth of know-how in such unglamorous fields of databases which are essential for the support of basic research, and possesses great R&D capabilities in the software field.

[In the following table, the element technologies in which much research has been done in Europe and America follow the symbol EA:, and those in which much research has been done in Japan follow the symbol J:.]

New Materials

1. High-temperature superconductors EA: Theoretical mechanism elucidation J: Composition improvement, processing
2. Nonlinear photoelectronic materials EA: Organic materials
3. Ferromagnetic materials J: Long history in inorganic metals and organic polymers
4. Molecular function materials EA: Research/researcher depth
5. Super-environment-resistant advanced composite materials EA: Defense-related technologies, materials in general
6. New alloys, intermetallic compounds EA: Aerospace related technologies in general J: Alloy technology
7. New-function fine ceramics EA: Basic science J: Optical-electronics
8. New-function carbon-based materials EA: New diamond static and dynamic pressure methods J: New diamond low-pressure synthesis
9. New-function glasslike (noncrystalline) materials EA: Theory, materials
10. High-purity precision macromolecular materials EA: Analysis, evaluation J: Separation and precision technologies
11. Silicon chemical materials EA: Monomers, polymers
12. New microelectronic materials EA: New phenomena J: Alloys

Electronics

1. Superconductor devices EA: Theory J: Integration
2. Quantified functional elements EA: Evaluation, general J: Thin film formation, microprocessing
3. Power electronics elements EA: High-output implementation
4. New optical functional elements EA: New materials, device concepts
5. Large-area circuit elements EA: Monocrystalline substrates J: Amorphous

Biotechnology

1. Functional enzymes, creation of biological substances EA: Genetic engineering
2. Animal- and plant-cell engineering EA: New concepts J: Variety, tissue manipulation
3. New genetic engineering EA: Plant and animal cells J: Implanting genes into cells
4. Bio-databank formation EA: Microbe banks, databases
5. Search for and classification of microbes, plants, and animals that will constitute new genetic resources EA: Preservation, breeding, providing research strains J: Collection and nurture of microbes
6. Technology for sophisticated utilization of biological reactions EA: Mechanism elucidation

Figure 2-1-1-10 Research by Advanced Nations in Basic Technology Fields [figure continued]

[Continuation of Figure 2-1-1-10]

Technologies Related to Both New Materials and Electronics

1. Precision atomic control technology EA: Wide research vision J: Analysis/synthesis control
2. New processes for creating metallic and inorganic materials EA: New processes
3. Precision atomic arrangement control technology EA: Analysis, evaluation
4. Evaluation, analysis, and measurement technologies EA: New concepts J: Improvement technology
5. Design and simulation technologies EA: Software
6. Optical reaction process technology EA: Basic ideas, lasers
7. Extreme environment creation technology EA: Superhigh temperatures, high vacuums, extremely low gravity

Technologies Related to Both Electronics and Biotechnology

1. Protein handling (arranging) technology EA: Genetic manipulation, microbiology
2. Biomembrane utilization technology EA: Structure, function elucidation
3. Development of biorelated analysis and evaluation systems EA: Analysis and evaluation systems in general J: Automation

Technologies Related to Both New Materials and Biotechnology

1. Life-function modeling technology J: More popular research in Japan
2. Organism adaptability technology EA: Artificial organs J: Some materials
3. Biochemical utilization technology EA: Molecular biology, genetic engineering
4. Bioprocess separation and refining technology EA: Basic technology

Software, Systemization

1. Self-managing information processing mechanisms EA: Human interfaces
2. Data processing mechanisms of the autonomic nervous system EA: Research/researcher depth
3. Super-parallel architectures EA: Architectures, networks
4. Managing software for machine control systems EA: Aerospace J: Element technologies
5. Software harmonization and development technology EA: Software accumulation
6. Disaster early-warning technology EA: Detection technology
7. Environmental control technology EA: Biological impact technology, acid-rain impact technology
8. Human technology EA: Cognition science, interfaces J: Processing ambiguous information
9. Natural resources and energy technology EA: Prospecting technology
10. Functional robot technology EA: High-speed implementation J: Home robotics

Note: Research levels determined on basis of previously publicized research results. Cf Appendix 3 for survey methods.

Subsection 2. Japanese R&D Efforts--Current Status

(1) We will here discuss the research and development work being done in Japan, evaluated in the following four areas:

A) R&D investment
B) Retention and training of qualified research personnel
C) Research environment
D) Research support infrastructure

(2) The following characteristic points became clear as a result of our studies.

A) Compared to the advanced Western nations, Japanese R&D expenditures are at a high level. The proportion of this burden taken on by the government is lower in Japan than in Europe and America, however, and the proportion spent on basic research is likewise lower.

B) Japan has more researchers [per capita] than any of the advanced Western nations, but the number of those trained for basic research is not necessarily adequate.

C) In general, Japanese research facilities are maintained at a high level. However, Japan lags behind Europe and America in the adequacy of its research support infrastructure, including facilities necessary for serious basic research

(3) We proceed now to an analysis of each of the four areas noted above in (1).

1. R&D Investment

When we examine the state of Japanese investment in research and development, we find that R&D investment in the private sector, which is focused heavily on applications and developmental research, is at the highest level in the world. Conversely, however, government expenditures on research and development is low. As a consequence, the work being done in Japan on basic research is inadequate when compared to the work being done in applications and developmental research.

(1) Trends in Japanese R&D Expenditure

<1> The top priorities in industrial technology in Japan's postwar reconstruction period were to rapidly regain prewar levels and to quickly attain levels close to those of the Western nations. The speed of technological development thus became of critical importance.

In December, 1949, the Agency of Industrial Science and Technology issued a publication entitled "Current Status of Japan's Mining and Industrial Technology." The following is an excerpt from that publication.

> Beyond any shadow of doubt, the advancement and expansion of technology is of critical importance in overcoming the adverse economic conditions in postwar Japan and establishing a strong, autonomous Japanese economy by promoting exports while raising the standard of living of the people. In view of the patent fact that the level of technology in Japan is generally behind at the present time, the problem becomes one of the speed with which we can advance and expand Japanese technology.... If Japanese technology fails to advance fast enough at this time, our efforts to establish a peaceful Japan will inevitably end in a fiasco.

<2> It was with such a consciousness as this that Japanese R&D activity made a new start. Subsequently, as the economy expanded, R&D activity increased at a steady rate, becoming increasingly centered in the private sector. This activity exhibited the most rapid growth of any advanced nation, particularly after the first oil shock, as the structure of industry became more knowledge-intensive. In 1985, Japanese expenditure in research and development as a fraction of GNP reached a level of par with the advanced Western nations (West Germany 2.83 percent, Japan 2.77 percent, United States 2.72 percent, France 2.33 percent, United Kingdom 2.32 percent).

<3> As a result, Japanese R&D expenditures increased rapidly, both as a fraction of GNP (19.4 percent in FY 1985), and as a fraction of total R&D expenditures among the five major advanced nations (20.2 percent in FY 1985). (Cf Figure 2-1-2-1).

(2) Largest Private R&D Expenditure Among Advanced Nations

<1> This recent rapid growth in Japanese R&D expenditure has been supported primarily by enormous R&D outlays in the private sector.

<2> As a fraction of GNP, Japanese R&D expenditure since the 1970's has been the outright leader among the major industrialized nations. This trend has been particularly pronounced since the second oil shock, and continues year after year to outstrip other nations by a widening margin (Cf Figure 2-1-2-2).

<3> As a fraction of total private R&D expenditure by the major industrialized nations, Japan's share has increased more than threefold over the past 20 years, reaching 26.8 percent in 1985 (Cf Figure 2-1-2-3).

<4> Underlying this prodigious R&D work in the private sector have been such supporting societal and economic factors as Japan's accumulated technological know-how, a highly educated and motivated work force, the existence of considerable markets, and the simulative influence of stiff competition between companies. This has been so particularly since the 1970's.

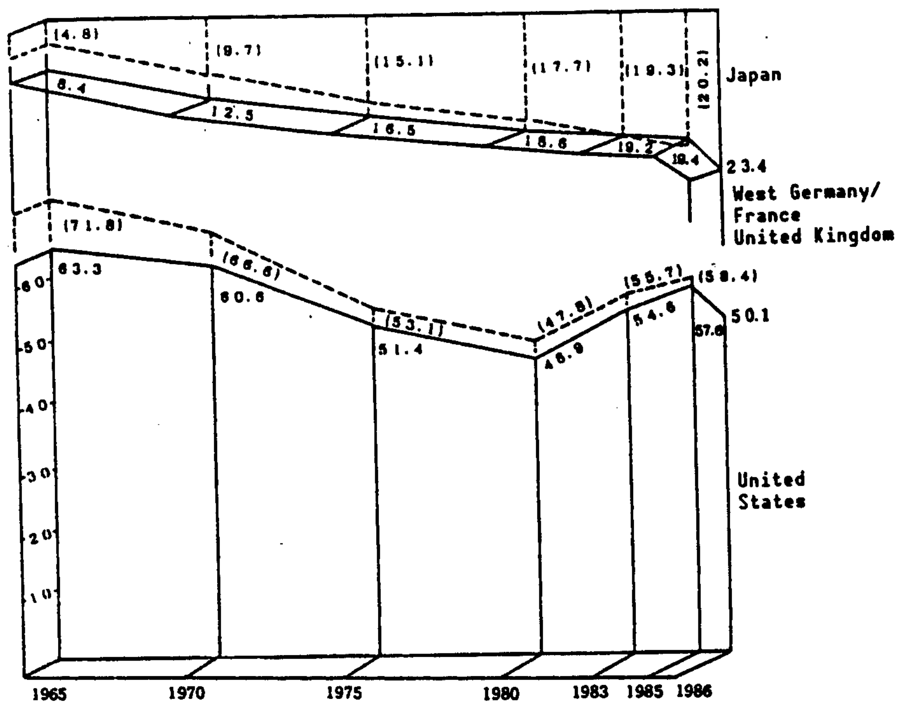

Figure 2-1-2-1 Trends in GNP and R&D Expenditures Among Five Major Advanced Nations (%) (———) GNP; ------ R&D expenditure)

Note: In evaluating the share represented by Japan's GNP in 1986, one must remember to consider the effect of exchange rates.

Sources:

Japan

"Survey on Scientific and Technological Research" (Management and Coordination Agency)

"National Economic Calculations [Kokumin Keizai Keisan]" (Economic Planning Agency)

United States

"National Patterns of Science and Technology Resources 1986" (NSF)

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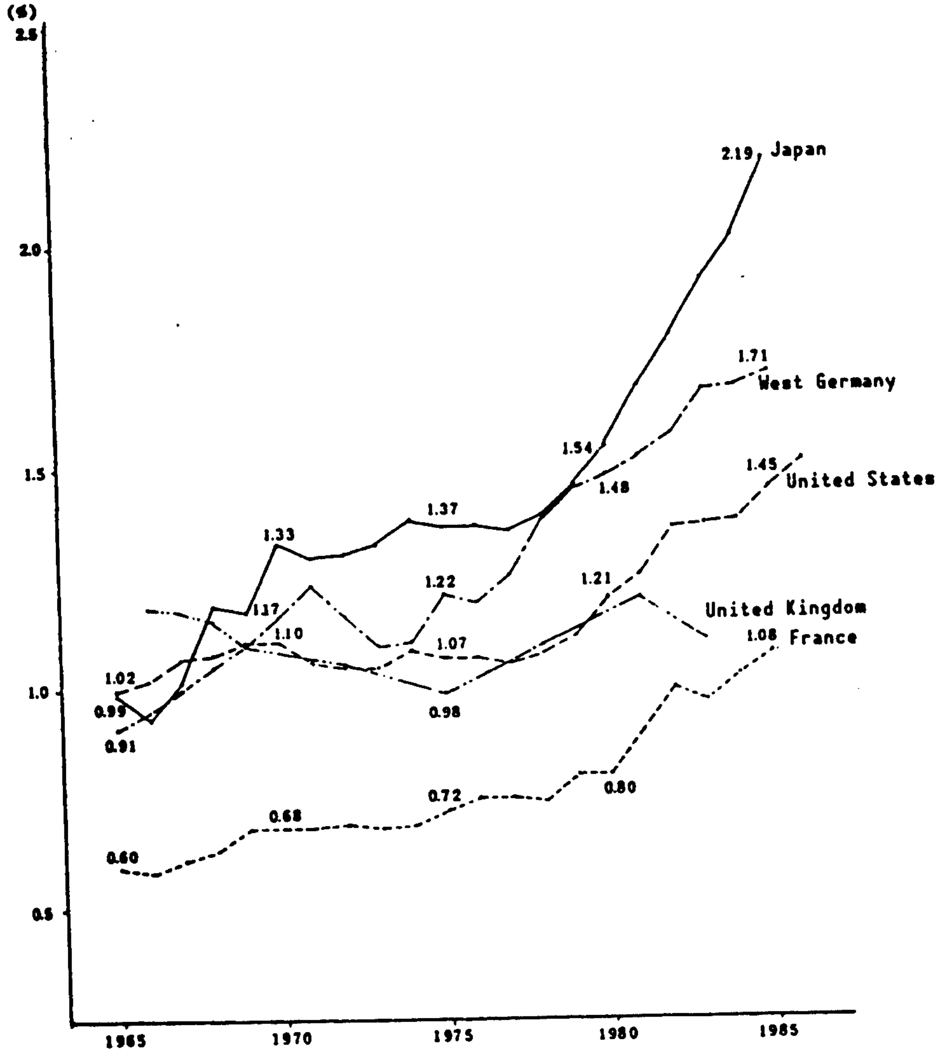

Figure 2-1-2-2 Trends in GNP Fraction of Private R&D Expenditure Among Five Major Industrialized Nations

Note: The division of R&D expenditure among government and private interests is as follows:

- Government.............National and regional public organizations, special corporations
- Private sector
  - Industry......Corporate and private research facilities
  - Universities......Private universities

Sources

Japan

"Survey on Scientific and Technological Research" (Management and Coordination Agency)

"National Economic Calculations [Kokumin Keizai Keisan]" (Economic Planning Agency)

[sources continued]

[Continuation of 2-1-2-2 Sources]
United States
"National Patterns of Science and Technology Resources 1986" (NSF)
IMF "International Financial Statistics"
West Germany
Faktenbericht 1986 zum Bundesbericht Forshung (Ministry of Research and Technology)
IMF "International Financial Statistics"
United Kingdom
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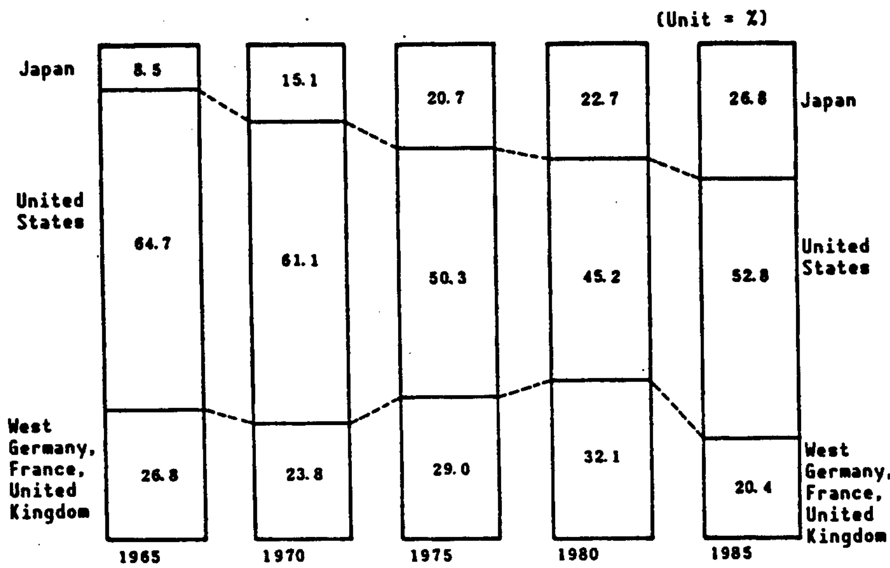

Figure 2-1-2-3 Japanese Share of Total Private R&D Investment Among Five Major Industrialized Nations

Sources
Japan
"Survey on Scientific and Technological Research" (Management and Coordination Agency)
United States
"National Patterns of Science and Technology Resources 1986" (NSF)
West Germany
Faktenbericht 1986 zum Bundesbericht Forshung (Ministry of Research and Technology)
United Kingdom
OECD Statistics
France
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Research and development have been continually promoted in Japan by the following factors:

A) Japanese private enterprise has had to cope with continual domestic and foreign competition in the areas of cost, product quality, and new product development. Private R&D efforts have also been stimulated and encouraged by governmental R&D projects and policies supportive of R&D activities.

B) During the era of rapid national growth, a reciprocal supply structure between industries and a strong mutual relationship between R&D and industrial growth functioned effectively through the mechanisms of intercompany competition and the tireless pursuit of product quality. It will be instructive to cite one example of this. R&D successes in the steel industry led to superior steel plate, which in turn stimulated further development in the automobile industry. As a result, demand rose in the automobile industry for higher grades of steel, thus stimulating the steel industry to further R&D efforts.

C) A series of structural changes in Japanese industry promoted research and development, and the latter promoted further industrial restructuring, in a beneficial cycle.

D) Consumer demand has been high for better performance, functionality, and design in consumer products.

E) Those engaged in production have exhibited strong creativity and the desire for improvement, and this has led to grassroots R&D efforts.

(5) Such upheavals in the economic environment as the dollar shock and the oil shocks have actually strengthened R&D efforts by Japanese industry. The second oil shock in particular enabled Japanese R&D activity to advance by a quantum leap (cf Figure 2-1-2-4). And, as we saw in Section 1, research and development in electronics--a key knowledge-intensive technology--promoted research and development on high-tech products in a wide range of other fields.

(6) In recent years, in some of the developing nations as well as in the advanced nations, there has been a desire to implement suitable forms of specialization. Domestically, meanwhile, market needs have become increasingly sophisticated. In this environment, Japanese industry has endeavored to further strengthen its R&D capabilities in the interest of moving into new commercial fields and developing products which are more functional and discriminating. At the same time, investment in research and development has been increased and greater priority has been given to basic research.

(7) In this manner, Japanese industry has expanded as technology has beefed up its technological development in coping with sweeping environmental changes.

However, industry-based R&D investment is highly susceptible to fixed-cost retrenchment during times of economic recession. There is also a limit to how much industry can invest in high-risk basic research and academic basic research.

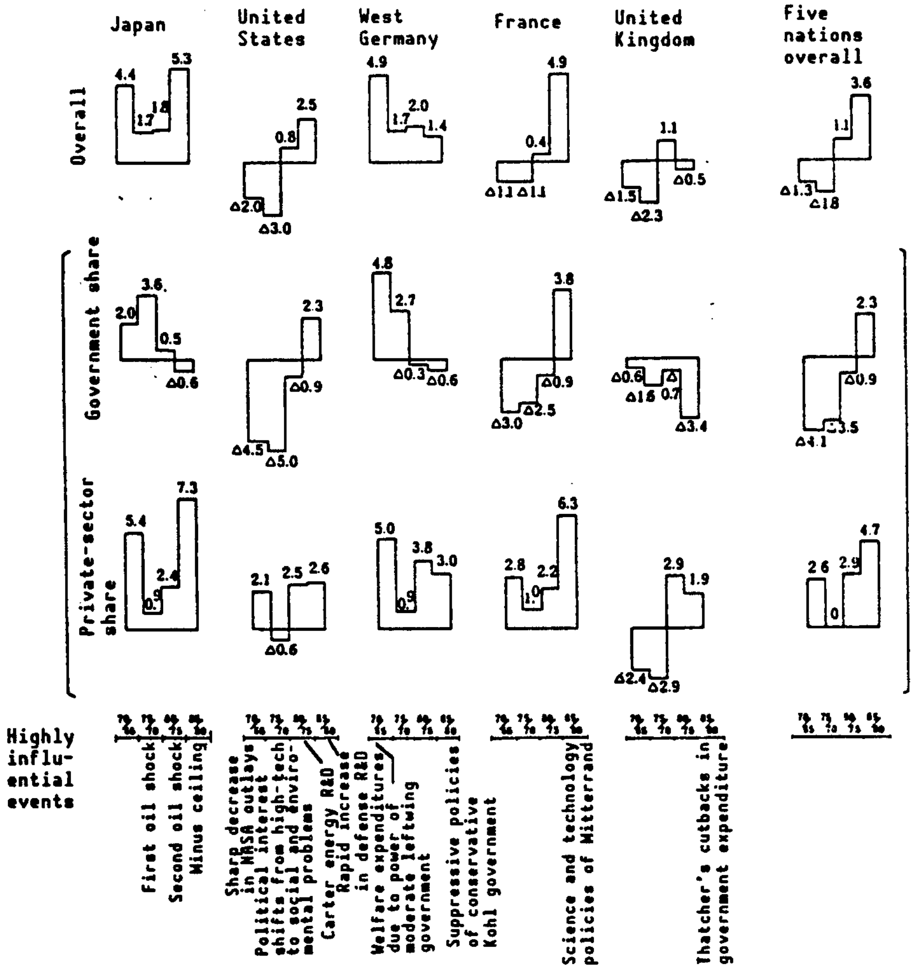

Figure 2-1-2-4 Analysis of Factors Underlying Changes in GNP Fraction of R&D Expenditures Among Five Major Industrialized Nations

Note: Numerical values indicate rate of change in R&D-expenses/GNP ratio.

Sources

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"Survey on Scientific and Technological Research" (Management and Coordination Agency)

"National Economic Calculations [Kokumin Keizai Keisan]" (Economic Planning Agency)

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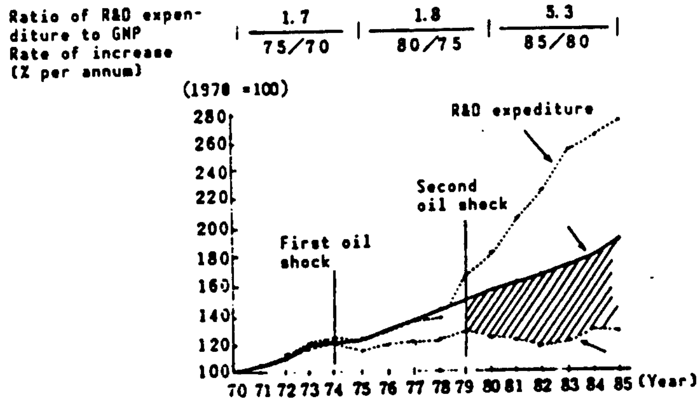

Figure 2-1-2-5 Trends in R&D Expenses and Actual GNP, Energy Consumption

Source: Prepared from MITI white paper

(3) Meager Governmental R&D Expenditure

<1> Looking at the area of government involvement, there has been little growth in government funding of research and development despite the enormous growth in R&D expenditure in the private sector.

<2> In general, the fraction of the total national budget allocated for science and technology is the lowest of all the advanced nations. (In FY 1985, France allocated 7.1 percent of its budget to S&T, the United States 5.1 percent, West Germany 5 percent, and the United Kingdom 3.4 percent, whereas Japan allocated a mere 2.9 percent) (cf Figure 2-1-2-6). In the 5-year period from 1981 to 1985, the real growth in budget allocations for science and technology was 17 percent in France, 13.3 percent in West Germany, 10.4 percent in the United States, 3.8 percent in the United Kingdom, and a paltry 0.1 percent in Japan (cf Figure 2-1-2-7).

<3> As a consequence, Japanese governmental R&D expenditures, as a fraction of GNP, have continued to fluctuate at roughly half the level exhibited in the other advanced nations (0.58 percent in FY 1985 as compared to 1.27 percent in the United States, 1.25 percent in France, 1.12 percent in West Germany, and 0.99 percent in the United Kingdom) (cf Figure 2-1-2-8). A very similar trend is seen in the percentage of R&D expenditure funded by the government (only 19.4 percent in FY 1985, compared to France 53.5 percent, United States 46.8 percent, United Kingdom 42.6 percent, and West Germany 39.6 percent) (cf Figures 2-1-2-9, 2-1-2-10, 2-1-2-11).

<4> The following factors are among those which underly this low level of government R&D expenditure in Japan.

A) Of the immediate R&D tasks which have faced Japan to date, most have involved technologies at the application and developmental research stage, relatively speaking, often in areas where Japan was behind in technical know-how. Hence, compared to the tasks undertaken by private industry, the tasks in which the government could become directly involved were few.

B) The government has limited its function largely to one of encouraging and stimulating R&D activities in the private sector. As a consequence, the contribution of government to the research and development done in private industry has been lower than in the advanced Western nations.

C) In the context of fiscal stringency, as compared to the advanced Western nations, considerable weight has been placed in fields other than science and technology in Japan.

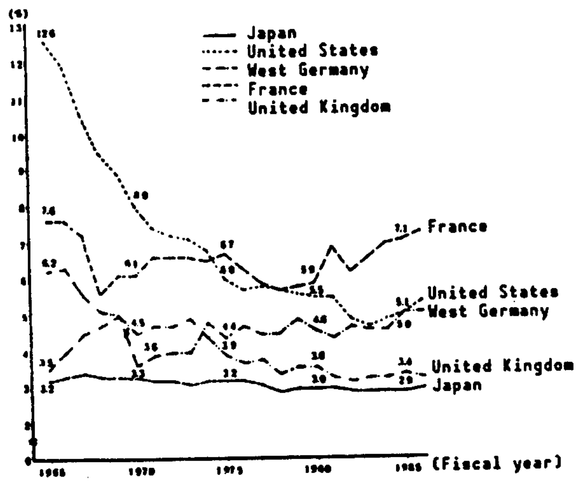

Figure 2-1-2-6 Allocations in National Budgets of Five Major Industrialized Nations for Science and Technology

Sources
Japan
National Budget
United States
Budget of the U.S. Government: Special Analyses
West Germany
Faktenbericht 1986, Statistische Information, Finanzbericht
United Kingdom
Annual Review of Government Funded R&D, The Government Expenditure Plan 1985-86 to 1987-88
France
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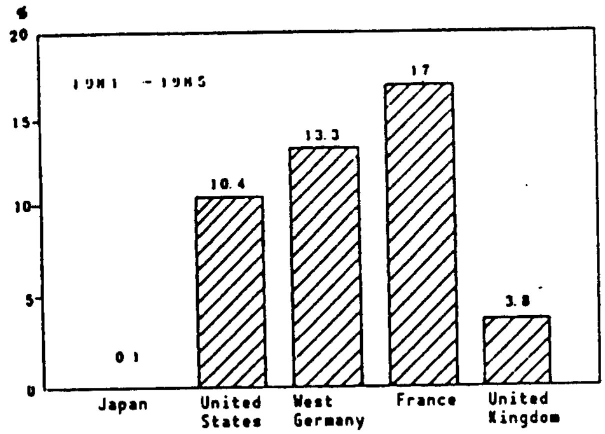

Figure 2-1-2-7 Real Growth in Science and Technology Budgets Among Five Major Industrialized Nations

Note: Numerical values in graph indicate real growth in 5-year period from 1981 to 1985.

Sources
Japan
National Budget
United States
Budget of the U.S. Government: Special Analyses
West Germany
Faktensbericht 1986, Statistische Information, Finanzbericht
United Kingdom
Annual Review of Government Funded R&D, The Government Expenditure Plan 1985-86 to 1987-88
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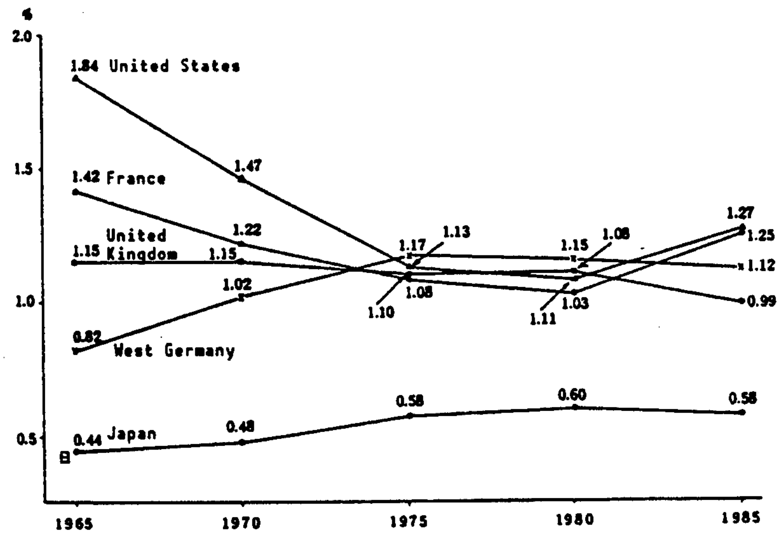

Figure 2-1-2-8 Trends in GNP Fraction of Government R&D Expenditure Among Five Major Industrialized Nations

Note: Data for United Kingdom from 1966, 1969, 1975, 1981, and 1985.

Sources

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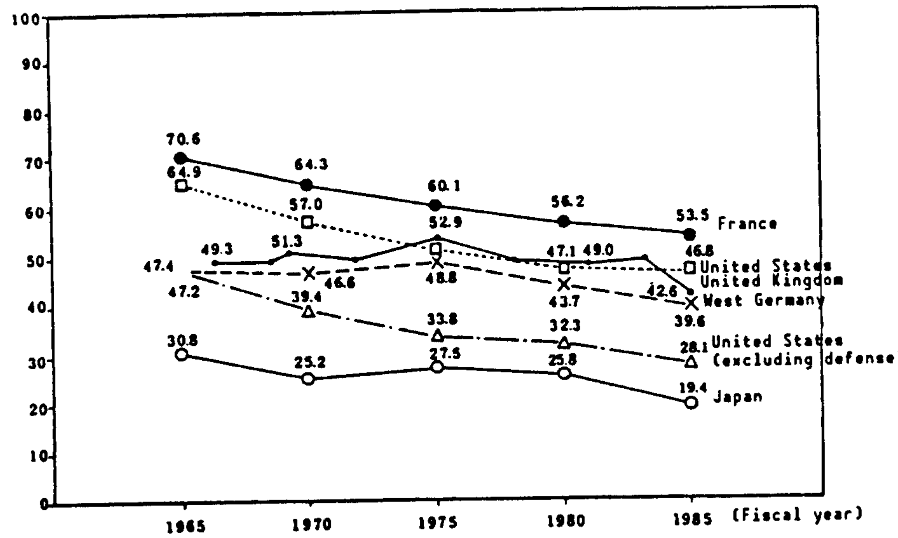

Figure 2-1-2-9 Trends in Government Contribution to R&D Expenditures Among Five Major Industrialized Nations

Notes:

1. Data for Japan represents natural science only; data for other nations represents totals for natural science, liberal arts, and social sciences.
2. Data for United Kingdom from years 1966, 1969, 1975, and 1981.

Sources

Japan

"Survey on Scientific and Technological Research" (Management and Coordination Agency)

United States

"National Patterns of Science and Technology Resources 1986" (NSF)

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Annual Review of Government Funded R&D 1987

OECD Statistics

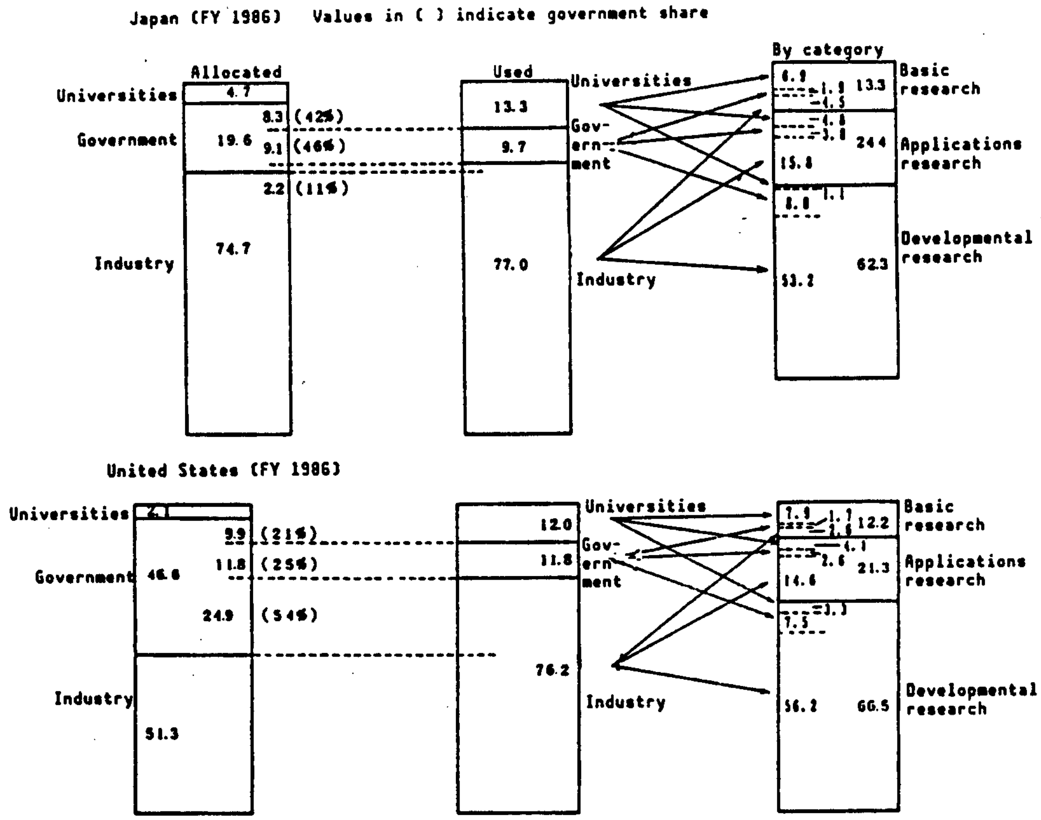

Figure 2-1-2-10 Comparison of R&D Funding in Japan, United States (percent)

Sources:
Japan
"Survey on Scientific and Technological Research" (Management and Coordination Agency)
United States
"National Patterns of Science and Technology Resources 1986" (NSF)

Japan Agency	Budgeted amount (x ¥100 million)	Percentage
Ministry of Education	8,130	47.6
Science and Technology Agency	4,310	25.3
MITI	2,212	13.0
Ministry of Agriculture, Forestry and Fishieries	666	3.9
Ministry of Health and Welfare	441	2.6
Defense Agency	827	4.8
Other agencies	479	2.8
Total	17,065	100.0

United States Agency	Budgeted amount (x $1 million)	Percentage	Excluding DOD
NSF	1,492	2.8	7.3
NASA	3,962	7.3	19.4
Department of Energy	4,941	9.1	24.2
Department of Commerce	360	0.7	1.8
Department of Agriculture	968	1.8	4.7
HHS	6,561	12.1	32.2
Department of Defense	33,776	62.4	--
Other agencies	2,102	3.8	10.4
Total	54,162	100.0	100.0

(Numerical values indicate expenditures)

Major NSF Projects (x $1 million)

Projects	1988
Training and human resources	273
Basic science and technology center(s)	529
Projects, facilities for strengthening academic fields	1,100

(Values indicate obligations)

Major NASA Projects (x $1 million)

Projects	1988
Space station	
Space transport system capabilities	
Space science and applications	
Commercialization projects	
Atmospheric research and development	
Aeronautical science research and technology	
Space research and technology	
Interagency support activities	

(Values indicate obligations)

Figure 2-1-2-11 Comparison of Governmental R&D Expenditures in Japan, United States (FY 1988) [figure continued]

[Continuation of Figure 2-1-2-11]
Major HHS Projects (x $1 million)

Projects	1988
National health facilities (AIDS)	6,318
Alcohol and drug abuse, mental health	561

(Values indicate obligations)

Major Department of Energy Projects (x $1 million)

Projects	1988
Defense projects	2,393
General scientific projects	625
Energy projects	2,053
• Basic energy projects	479
• Clean coal technology project	200
• Solar and other alternate energy technology	103
• Energy conservation R&D projects	75
• Nuclear fission energy technology	334
• Nuclear fusion energy technology	346
• Biological science projects, environmental projects	218

(Values indicate obligations)

Major Defense Department Projects Budgeted (x $1 million)

Projects	1988
Technological infrastructures	3,141
Advanced technological development	5,534
Strategic projects	7,817
Tactical projects	12,509
Information, communications projects	4,797
Project administration and support	3,866

(Values indicate obligations)

FY 1988 budgeted amounts for United States are estimates
Source: "Special Analysis 1989," U.S. Office of Management and Budget

(4) Low Level of Government Subsidization of R&D in Industrial Sector

<1> The contribution which government makes to industrial sector R&D expenditures in Japan is less tan 10 percent of what it is in the advanced Western nations. (The respective government shares in FY 1986 were 3.1 percent in Japan, 34.2 percent in the United States, 23.2 percent in West Germany, 26.5 percent in France, and 23.1 percent in the United Kingdom) (cf Figures 2-1-2-12, 2-1-2-13).

(Unit: percent)

		Industry	Government	Universities	Foreign
Japan (1986) (3.1)*	Funded:	76.0	19.4	4.6	0.1
	Used:	77.1	9.7	13.2	-
United States (1986) (34.2)	Funded:	51.3	46.6	2.1	-
	Used:	76.2	11.8	12.0	-
West Germany (1985) (23.2)	Funded:	60.3	38.6	-	1.1
	Used:	82.1	3.7	14.2	-
France (1985) (26.5)	Funded:	42.4	53.8	0.2	3.6
	Used:	57.7	26.4	15.9	-
United Kingdom (1985) (23.1)	Funded:	45.5	48.9	0.4	5.3
	Used:	65.9	22.7	11.4	-

*Numerical value in ( ) is percentage of industry sector R&D expenditure funded by government.

Figure 2-1-2-12 Government Funding of Industrial Sector R&D Expenses in Five Major Industrialized Nations

Notes:

1. Data for amounts funded/used by category based on following FY years: Japan 1985, United States 1986, West Germany 1985, France 1983, United Kingdom 1985.
2. The categories for R&D funding utilization are as follows:
   - Government: National and private research organizations, special corporations (research laboratories, foundations, etc.)
   - Universities: National, public, and private universities
   - Industry: Companies, special corporations (public corporations, etc.), private research institutions

Sources

Japan

"Survey on Scientific and Technological Research" (Management and Coordination Agency)

United States

"National Patterns of Science and Technology Resources 1986" (NSF)

West Germany

Faktenbericht 1986 zum Bundesbericht Forshung (Ministry of Research and Technology)

France

Project de Loi de Finances Pour 1988

International Statistical Year (OECD)

United Kingdom

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Economic Trends (Central Bureau of Statistics)

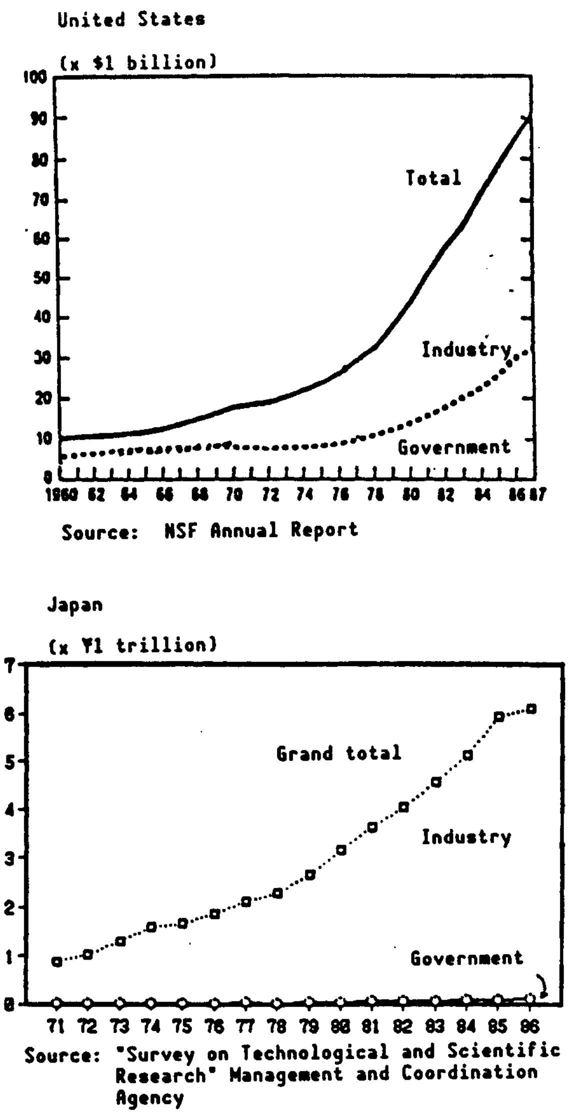

Figure 2-1-2-13 Trends in Industrial Sector R&D Expenditures by Funding Source

Source: "Survey on Technological and Scientific Research" Management and and Coordination Agency

<2> However, when we compare the percentages of R&D funds utilized by industry, government, and universities, respectively, in Japan with those in the advanced Western nations, we find that the disparities are not so great as in <1> above. Japanese utilization rates are roughly the same as those of the United States.

<3> This indicates that, in the advanced Western nations, a not insubstantial percentage of government R&D funding (including defense-related R&D expenditure) is being used for research and development in the industrial sector.

(5) Low Level of R&D Expenditure in Basic Research Fields

<1> When we examine the proportions of R&D funding which are allocated to basic research, we find that the proportion fluctuates at a lower level in Japan than in the other advanced nations (cf Figure 2-1-2-14). We find further that, as a fraction of GNP, Japan's basic research expenditures are at a low level as compared with the United States, West Germany, and France, ranging roughly from 50 percent to 75 percent of the level seen in those nations (cf Figure 2-1-2-15).

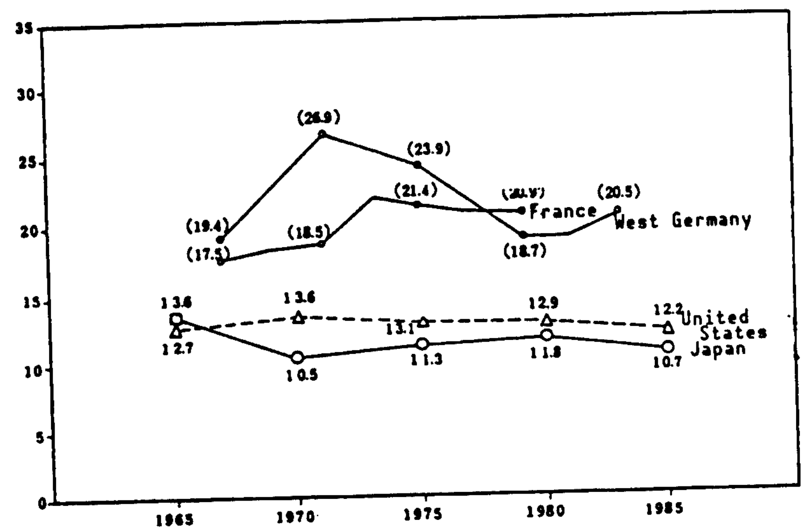

Figure 2-1-2-14 Basic Research Fraction of R&D Expenditure (OECD Basis)

Notes: 1. With the OECD method, the numbers of researchers are counted after conversion to full-time equivalents when comparing international science and technology statistics, but this is not done in the Japanese statistics. For this reason, Japanese data on researchers and research expenditures are subjected to the conversions noted below before making international comparisons.
In view of their dual roles as researchers and educators, numbers of university researchers are multiplied by a factor of 0.5, and corresponding research expenditures by a factor of 0.6.
2. Data for West Germany and France are from 1967, 1971, 1975, 1979, and 1983.

Sources
Japan
"Survey on Scientific and Technological Research" (Management and Coordination Agency)
United States
"National Patterns of Science and Technology Resources 1986" (NSF)
West Germany and France
OECD Statistics

(Unit: percent)

	Japan	United States	West Germany	France
Basic research expenditure as fraction of GNP	0.26 (1986)	0.34 (0.32) (1986)	0.56 (1983)	0.42 (1981)
Basic research ratio	11.1 (1986)	12.2 (17.6) (1986)	20.5 (1983)	20.9 (1979)
Basic research ratio by category				
Industry:	6.5	4.7	5.0	3.7
Government:	13.6	14.3	39.8	19.2
University:	54.2	58.1	76.4	90.0

Note: Values in ( ) exclude defense-related research expenditure

Figure 2-1-2-15 International Comparisons of Basic Research Expenditure (OECD basis)

Sources

Japan

"Survey on Scientific and Technological Research" (Management and Coordination Agency)

United States

"National Patterns of Science and Technology Resources 1986" (NSF)

West Germany

Faktenbericht 1986 zum Bundesbericht Forshung (Ministry of Research and Technology)

France

Project de Loi de Finances Pour 1988

United Kingdom

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OECD Statistics

<2> One reason for this low level is that, compared to the other advanced nations, government-funded research expenditure itself (of which basic research expenditure is the major component) is low in Japan.

By calculation we find that actual government-funded basic research expenditure, as a percentage of GNP, is only 0.10 percent, which ranges from a half to a third of the level seen among the other advanced nations (0.22 percent in the United States, 0.27 percent in West Germany) (cf Figures 2-1-2-16, 2-1-2-17).

In Japan, moreover, the private sector-funded basic research expenditure, as a fraction of GNP, is 0.16 percent. While this is higher than the government-funded fraction, most of this represents research that, while called basic research, is actually closer to applications research.

	Japan	United States	West Germany
Government-funded basic research expenditure as fraction of GNP(%)	0.10 (Note 1)	0.22	0.27 (Note 2)

Figure 2-1-2-16 Government Funding of Basic Research (OECD basis)

Notes: 1. It is assumed that government-funded research expenditures in industry and the university are used in basic research at the corresponding basic research ratio.
2. It is assumed that the fraction of state funding allocated to basic research is the same as that of the federal government.

Sources
Japan
"Survey on Scientific and Technological Research" (Management and Coordination Agency)
United States
"National Patterns of Science and Technology Resources 1986" (NSF)
West Germany
Faktenbericht 1986 zum Bundesbericht Forshung (Ministry of Research and Technology)

(Unit: trillion yen)

	Japan	United States
Total basic research expenditure	14	45

Source: Agency of Industrial Science and Technology

Figure 2-1-2-17 Technostock (Basic research expenditure--Aggregate totals for 1965-1985) (1980 prices)

<3> In recent years in Japan, particularly in the context of the R&D System for Next-Generation Industries (so-called "Next-Generation System"), we have seen a move toward upgrading basic research efforts in areas closer to real basic science. We have seen a similar trend in private industry, where more funding and human resources are being channeled toward far-reaching basic research projects. As of this writing, however, we do not see these trends as greatly changing the overall approach to basic research in Japan.

2. Acquisition and Training of Research Personnel

<1> The number of Japanese researchers is steadily increasing. In terms of the number of those engaged primarily in research per thousand employees, Japan is now at the highest level even among the advanced nations (cf Figures 2-1-2-18, 2-1-2-19, 2-1-2-20).

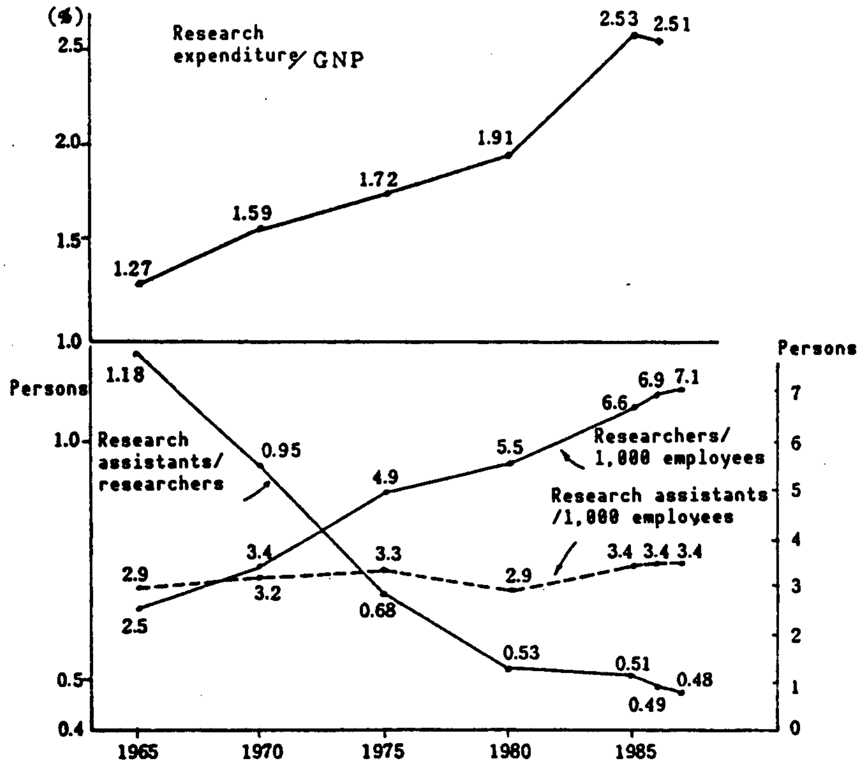


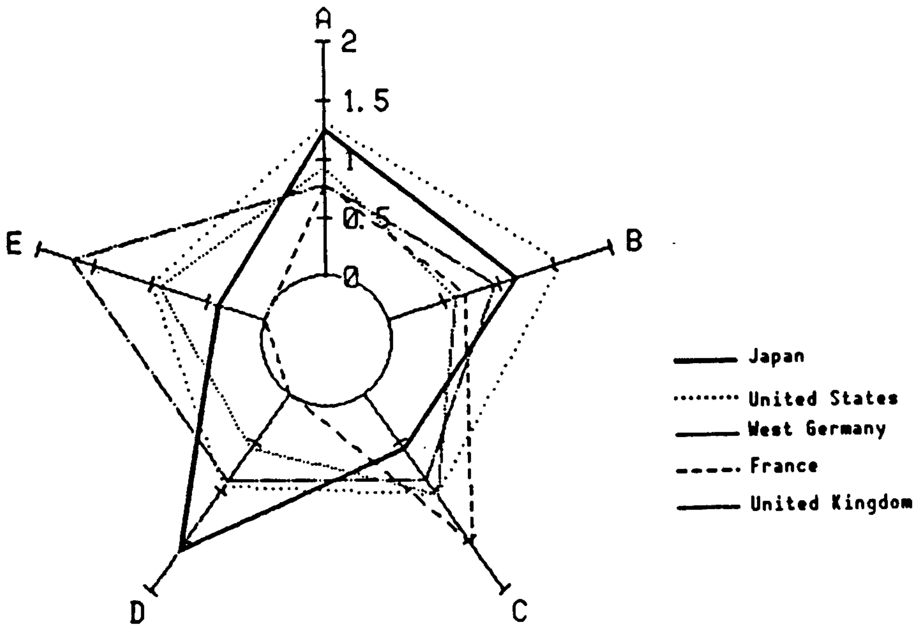
Figure 2-1-2-18 Trends in Numbers of Researchers, Research Assistants

Notes: 1. Numbers of research assistants represent totals of technicians, and research assistants in Management and Coordination Agency survey.
2. Data on research expenditure, researchers, and research assistants are for natural sciences only.

Sources: "Survey on Scientific and Technological Research" (Management and Coordination Agency)
"Work Force Survey" (Department of Labor)

<2> When we examine the educational credentials of research personnel, we find that the numbers of degree holders (bachelor's degree or above) per capita are much higher in Japan than in West Germany, France, or the United Kingdom. The percentage of those receiving higher education in Japan is also very high. Notwithstanding these facts, a) the per-capita ratios of those holding master's and PhD degrees (and thought to possess a high level of research capability) is lower in Japan, and b) when classified by major, those holding scientific degrees are fewer than those holding engineering degrees.

It may be argued that these trends are changing, in view of the gradually rising rates at which students are acquiring advanced degrees as compared to 10 years ago, and the gradual increase in the proportion of students taking scientific degrees. Nevertheless, at the present time, Japan lags behind in its training of personnel who can play a major role in creative basic research (cf Figures 2-1-2-19, 2-1-2-20).



	A: Researchers per 1,000 employees	B. Degree holders per 1,000 employees	C. (%) degree holders holding advanced degrees	Breakdown of degree holders by major (%) D: Engineering	E. Science
Japan (1985)	8.3 (7.1)* (1987)	1.16	15	59	11
United States(81)	7.5 (1985)	1.57	27	35	27
West Germany(83)	5.3	0.61	27	21	25
France (1983)	4.4	0.70	40	—	—
United Kingdom(83)	4.4**	0.97	20	33	46
Average	5.7	1.00	26	37	27

Figure 2-1-2-19 Researcher Training and Acquisition

Notes:
* Values in ( ) are corrected to OECD basis
** Data for United Kingdom does not include university researchers

Sources: "Trends in Major Indicators for Japanese R&D Activity" (Agency of Industrial Science and Technology)
"International Comparison of Educational Indices" (Department of Education)
"1962 Annual Science and Technology White Paper" (Science and Technology Agency)

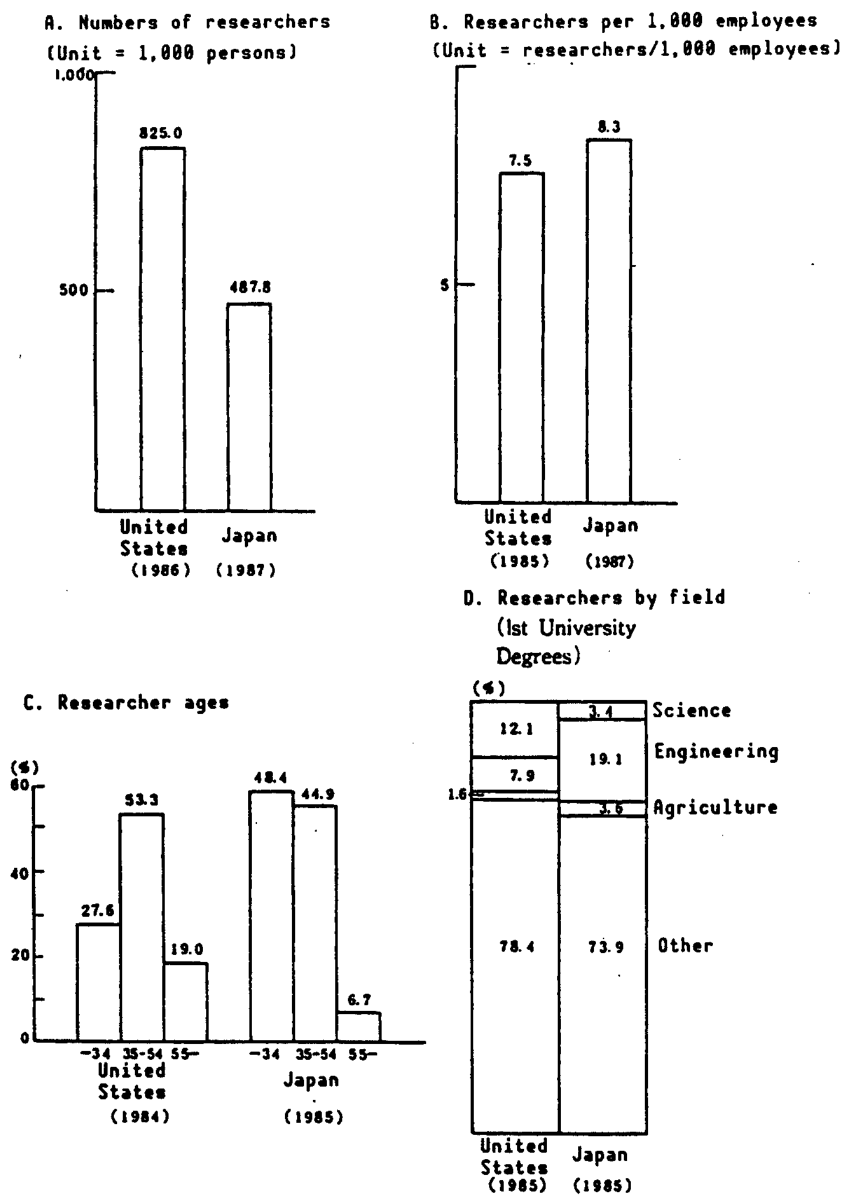


Figure 2-1-2-20 Comparison of Japanese and American Research Personnel

Source: NSF "Science and Engineering Indicators"

3. Research Environment

<1> In the area of the environment in which researchers work in Japan, the following problems have been pointed out:

(A) Compared to the United States, in Japan there are many restrictions which impinge on the free exchange of researchers between national research institutes, universities, and corporate research facilities (cf Figure 2-1-2-21).

	United States	Japan
Research cooperation with private industry		
Consulting work for private industry	OK	OK sometimes
Joint research with private industry	OK	OK sometimes
Formation of private industry (ventures, etc.)	OK	Not allowed
Acceptance of researchers from private industry	Yes	Yes
Retention of researchers for a specific period	Yes	No

Figure 2-1-2-21 Comparing Japanese and U.S. Restrictions on Activities of Civil Servants Engaged in Research and Education

Source: Agency of Industrial Science and Technology

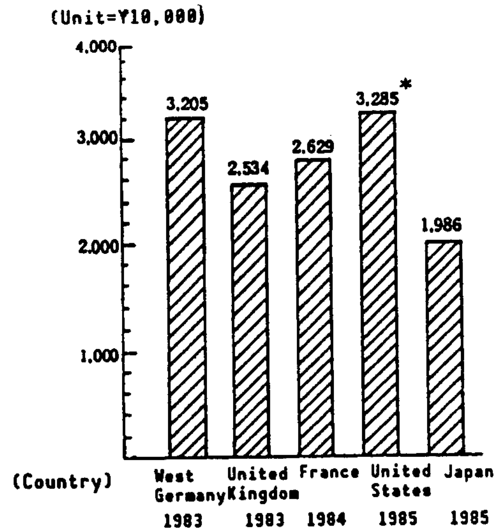
In May 1986, the "Research Exchange Promotion Act" was passed for the purpose of promoting free exchanges between university and private sector research interests by establishing the necessary new programs and institutions or modifying existing ones. At this writing, only three foreigners have ever been assigned to a Japanese national testing and research facility (as of 1 January 1988), and only four foreign researchers have ever held temporary positions at civilian research facilities (as of 1 October 1987). The number of private sector researchers invited to work at our national universities in conjunction with joint research carried on with private industry has risen from a mere 66 in 1983 to 465 in 1987, but this still falls short of an adequate level. (Note: These figures were reported by the Joint Research Program for national universities (including national universities and national industrial technical high schools).)

In the United States, research exchange is conducted relatively freely between private industry and both private and state universities. By comparison, the situation with respect to the exchange of researchers in Japan still has room for much improvement.

B) In Japan, most research efforts are done by research teams. As a result, although it is difficult to generalize on this point, the number of research assistants is small compared to research facilities in the other advanced nations (cf Figure 2-1-2-22).

C) It is said that, compared to other countries, Japan has relatively few people who are capable of directing, coordinating, and evaluating research efforts.

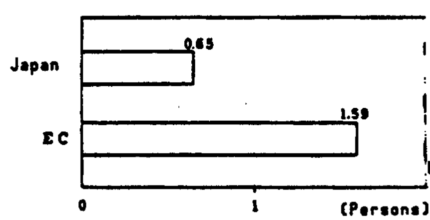
A. Research funding per researcher



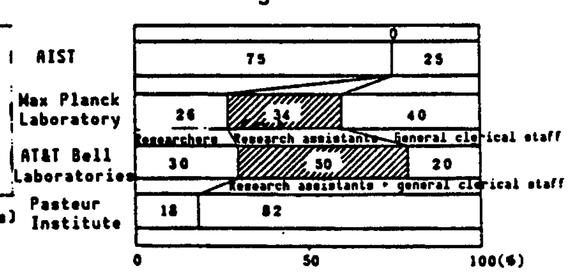
• Data for United Kingdom represents natural sciences only; data for other countries represents total for natural sciences, liberal arts, and social sciences.
• Data for United Kingdom is from industry and within the government.
* Asterisk indicates projected value.

Sources
Japan
"Survey on Scientific and Technological Research" (Management and Coordination Agency)
United States
NSF statistics
West Germany
Faktenbericht 1986 zum Bundesbericht Forshung (Ministry of Research and Technology)
United Kingdom
OECD Statistics
France
Appendix to Budget Proposal

B. Number of research assistants per researcher (1981)



C. Comparison of research workers at major research laboratories



Source for B: OECD Science and Technology Indicators (1986)
Source for C: Agency of Industrial Science and Technology

Figure 2-1-2-22 Research Support Programs

<2> With respect to the problems which face researchers in Japan, the following points need also to be studied:

A) Seniority System for Researchers

It is said that, in general, creative research is produced by researchers in their twenties, or at the oldest in their thirties. Japanese research staffs are most commonly organized along seniority lines, however, which may not be the best climate for the expression of creativity by younger researchers.

B) Establishment of Research Environment Suitable to Era of Internationalization

As international exchange becomes increasingly practiced, younger researchers want to work in more adventitious research environments, and are seeking positions overseas where they can give freer expression to their creative research capabilities. Japan needs also to establish a better research environment which is internationally open, taking full advantage of the high technology levels in Japan and the more uniform levels of competence exhibited by its own researchers.

C) Drain of Science and Engineering Majors Away From Manufacturing Fields

In recent years, the movement of science and engineering majors into such nonmanufacturing fields as banking, securities, and other financial fields has become quite pronounced. It is predicted that this trend will become even stronger as an increasingly service-oriented economy results in further structural changes and multicompany fusion in industry.

In the United States, there is an increasingly strong trend for outstanding students to seek the MBA degree after getting a bachelor's degree in science or engineering. There are growing fears that this trend will erode U.S. capabilities in scientific and technological fields. In Japan it will become necessary to carefully study and evaluate the problem of the drain of science and engineering majors into nonmanufacturing fields.

4. Research Support Infrastructure

<1> As R&D operations have become more complex and sophisticated, and as they have grown both quantitatively and qualitatively, the importance of the infrastructure (databases, joint-use facilities, supply of standard substances and other R&D materials, standardization of testing and evaluation methods, etc.) needed to support these operations has also grown.

<2> Although the establishment and maintenance of standard research facilities in Japan is generally at a high level, we lag behind Europe and America in terms of the facilities and equipment required for serious basic research. There are, of course, historical factors which have been influential in bringing about this situation. For example, in the field of chemistry, there is a need for a publication which provides an index of the

chemical literature which is indispensable for research and a listing of chemical substances discovered to date. This need was met early on in the United States by the publication of Chemical Abstracts, which became the vehicle for collating international chemical information. Japan also contributes to this creation of internationally used databases by submitting data.

<3> We will now examine the condition of the infrastructure which supports R&D activity, looking at databases, large experimental research facilities, the system for providing standard substances and microbial strains, and the work being done in standardization.

A) Databases

There are now said to be a total of some 1,800 databases being used in Japan today. Of these, however, only 425, or about 24 percent, were created in Japan. When our focus is narrowed to include only those databases related to natural science and technology, moreover, only 66 (approximately 3 percent) were created in Japan (cf Figure 2-1-2-23).

Field	Produced overseas	Produced domestically	Total
Natural sciences, technology	429	66	495
Social sciences, liberal arts	62	2	64
General	258	98	356
Other	1	1	1
Total	1,370	425	1,795

Source: "Database Index" (MITI, 1987 edition)

Internationally, the awareness of the importance of technological information is rising. We need to create information retrieval systems which correspond to the high level of technology in Japan.

B) Large Experimental Research Facilities

As the interaction between science and technology intensifies, the importance of basic research is growing. It is also becoming increasingly necessary to control and modify the structure of substances at the molecular and atomic levels, but such research activities require large facilities which provide radiation sources and extreme environments. In order to cope with global environmental problems and resource and energy limitations, moreover, aerospace and marine research facilities must also be made a part of the research support infrastructure. With the exception of the large particle accelerator (TRISTAN, Transposable Ring Intersecting Accelerator in Nippon), Japan lags far behind Europe and America in such large experimental research facilities (cf Figure 2-1-2-24 [not reproduced]).

C) System for Providing Standard Substances, Microbe Strains

Standard substances are substances which are used as standards when measuring the physical properties or compositions of other substances. They are used widely in measurement and chemical analysis in calibrating measuring instruments and evaluating measurement methods. Hence they contribute greatly to international product transactions and to factory quality control.

In such advanced developmental fields as new materials and biotechnology, accurate evaluation of the properties of substances is indispensable, and this demands the institution of a system for stably providing the standard substances on which such evaluation is based. In Japan, some standard substances are maintained at the National Chemical Laboratory for Industry (operated by the Agency of Industrial Science and Technology), but this provides neither an organized program for the distribution of standard substances nor a system for centrally administrating standard substance information. Thus, Japan lags considerably behind the United States, where the National Bureau of Standards (NBS) works in conjunction with other institutions to provide a centralized administration and distribution system for standard substances (cf Figure 2-1-2-25 [not reproduced]).

In order to promote biotechnology research, one must have access to standard, genetically controlled microbial strains. In this area too the research environment in Japan is inadequate (cf Figure 2-1-2-26).

D) Standardization

In the past. standardization has primarily been concerned with mass-produced products, playing an important role in insuring compatibility, improving product quality and utility, and streamlining production. In recent years, however, the time which elapses from the R&D stage to the manufacturing stage has tended to become dramatically shorter. As a consequence, the need for standardization even in the R&D stage has become stronger. In addition, the early standardization of evaluation procedures and terminology for new technologies has come to be very important as part of the supporting infrastructure for research and development. In Japan, therefore, standardization work is being pushed ahead in such advanced technological fields as information, new materials, biotechnology, and factory automation.

The international exchange of products and technologies has now become commonplace, making standardization extremely significant in terms of the international R&D infrastructure. For this reason, Japan is engaged in international standardization efforts, including those pertaining to advanced technological fields, primarily through the International Standardization Organization (ISO) and the International Electrotechnological Commission (IEC). In the ISO, Japan is playing a central role in drafting long-range plans for responding promptly to the needs for international standardization as they arise. Even so, in view of its technological and economic power, Japan is now expected to make even greater international contributions in this field. In order not to disappoint those expectations, we need to engage even more actively in international standardization work.

E) Arenas for International, Interdisciplinary Exchange

In Japan, there are a number of well-established academic and cooperative societies which promote inter-researcher exchange. Nevertheless, as compared to the Western nations, there are few arenas or forums in Japan for international and interdisciplinary exchange between first-rate researchers. Through the academic and cooperative societies in America and Europe, for instance, such exchange between researchers is conducted face-to-face as well as through the medium of society journals. Not only does this play a major role in forming information-sharing networks among researchers, it also provides an avenue for the sharing of all kinds of concepts and ideas, and hence has an infrastructural function in stimulating creative research (cf Figure 2-1-2-27 [not reproduced]).

Japan also needs to create such internationally open arenas to facilitate freer exchange between researchers.

Subsection 2. **Leading Edge of R&D in Private Industry**

The research and development done in Japanese private industry accounts for 73 percent of total Japanese R&D funding (the manufacturing industries alone account for 68 percent), and 62 percent of those engaged full-time in R&D activities (manufacturing industries = 59 percent) (FY 1986; cf Figures 2-2-2-1, 2-2-2-2). Thus, private industry accounts for the major portion of Japanese research and development.

In this section we analyze trends in private industry R&D from two perspectives, namely 1) the leading edge of R&D in high-tech products, and 2) trends in R&D in major industries.

1. Leading Edge of R&D in High-Tech Products

The trends at the leading edge of research and development in high-tech products are noted in Figure 2-2-2-3. The following points should be noted in these trends.

(1) Raw-Material-Related Products

The following trends are observed in the leading edge of R&D being done in raw-material-related high-tech products.

A) In recent years, in developing new products and in improving existing ones, much R&D work has centered on controlling intricate structures at the atomic and molecular levels for the purpose of achieving the desired functions and performance. This work has made use of knowledge accumulated in basic science fields, and comprehends such products as high-tensile steel, new glass, conductive polymer materials, composite materials, and optical fibers.

B) As a result of the R&D advances being made in this direction, the relationship between functions and performance on one hand, and atomic and molecular structure on the other, is again becoming a major topic of research in some cases. Superconductors and polymer separation films are two examples.

C) Other R&D themes which have become very important include such advanced process technologies as ultrathin film formation and precision molding, and technology for evaluating the functions and performance of newly devised products. This aspect of R&D involves such fields as fine ceramics, amorphous alloys, and engineering plastics.

	R&D expenses						Research personnel			Technology trade				
	R&D expenses		Ratio of R&D expenses to sales	R&D expenses--percentage by type (%)			Engaged full-time in research		R&D expenses per person engaged in R&D (¥ million)	Technology exports		Technology imports		Technology exports/imports
	(¥ billion)	%	(%)	Basic	Applications	Developmental	(x 1,000 persons)	%		(¥ billion)	%	(¥ billion)	%	
Overall	8,415	100	–	13.3	24.4	62.3	406	100	20.1	–	–	–	–	–
Government	1,481	17.6	–	–	–	–	* 102	25.1	14.4	–	–	–	–	–
Private sector	6,934	82.4	–	–	–	–	* 304	74.9	22.0	–	–	–	–	–
Private research organizations, univ.	814	9.7	–	–	–	–	52	12.8	15.0	–	–	–	–	–
Industries (companies)	6,120	72.7	2.57	6.1	21.6	72.3	252	62.1	24.3	2241	100	2606	100	0.86
Basic materials industries	380	4.5	0.78	6.1	29.7	64.2	12	3.0	31.7	306	13.7	22	0.8	13.91
Nonmanufacturing industries	5,740	68.2	3.03	6.1	21.1	72.9	240	59.1	23.9	1935	86.3	2584	99.2	0.75
Manufacturing industries	1,850	22.0	2.73	9.1	25.7	65.2	74	18.2	25.0	739	33.0	698	26.8	1.06
Processing assembly industries	3,548	42.1	4.18	4.3	18.1	77.6	146	36.0	24.2	1055	47.0	1700	65.2	0.62
Consumer-oriented industries	260	3.1	0.89	8.3	29.0	62.7	15	3.7	17.9	102	4.6	152	5.9	0.67
Other industries	82	1.0	1.07	6.6	17.9	75.6	5	1.2	17.4	39	1.7	34	1.3	1.15

R&D Breakdown (Figures in parentheses are percentages of whole)

	R&D expenses total (¥ billion)	Labor costs	Raw material costs	Purchases of tangible fixed assets	Real estate	Machines, tools, systems, etc	Other	Other expenses
Private industry	6,120(100)	2,524(41)	1,252(20)	959(16)	197(3)	712(12)	50(1)	1,385(23)
Manufacturing industries	5,740(100)	2,401(42)	1,201(21)	847(15)	177(3)	622(11)	48(1)	1,291(22)
Nonmanufacturing industries	380(100)	123(32)	51(13)	112(30)	20(5)	90(24)	2(1)	94(25)

Note: An asterisk (*) indicates that some estimates were made due to difficulties in statistical classification.

Source: Prepared from "Scientific and Technological Survey Report," General Affairs Agency

Figure 2-2-2-1 Positioning of Private Industry R&D (FY 1986, Natural science fields)

	R&D expenses		Expenses by type of research			Ratio of R&D expenses to sales	Researchers		R&D expenses per person engaged full time in research (¥10,000	Technology trade		
	R&D expenses (¥100 million)	Percentage of whole (%)	Basic (%)	Applications (%)	Developmental (%)	(%)	Engaged full-time in research (persons)	Percentage of whole (%)		Technology exports proceeds (¥100 mil)	Technology imports payments (¥100 mil)	Technology exports/technology imports
All industries	61,202	100.0	6.1	216	723	257	251,771	1000	2,431	2,241	2,608	086
Agriculture, forestry, fisheries	43	0.1	15.5	170	675	024	197	01	2,183	1		
Mining	217	0.4	17.5	220	605	116	698	03	3,109	4	2	150
Construction	1,211	2.0	5.9	303	638	055	5,752	23	2,105	208	18	1156
Manufacturing industries	57,396	938	6.1	211	729	303	239,792	95.2	2,394	1,935	2,584	075
Basic material industries	18,502	30.2	9.1	25.7	65.2	273	74,016	294	2,500	739	698	106
Steel	2,553	4.2	6.0	28.2	658	254	5,405	21	4,723	215	58	371
Chemical	9,836	16.1	11.5	282	602	131	12,523	16.9	2,313	382	406	094
Other	6,113	10.0	6.3	20.6	731	176	26,098	104	2,343	142	234	061
Processing and assembly	35,481	58.0	4.3	181	77.6	118	116,574	582	2,421	1,055	1,700	062
General machine industries	3,791	6.2	45	20.5	750	277	21,313	85	1,779	68	245	027
Electric machines	19,800	32.4	4.1	18.4	775	550	89,821	357	2,204	530	913	058
Automobiles	8,404	13.7	4.8	15.4	798	320	18,985	75	4,427	402	113	356
Other	3,486	5.7	4.2	207	751	392	16,152	65	2,119	55	120	113
Consumer-oriented industries	2,602	4.3	83	290	627	089	11,525	58	1,791	102	152	067
Textiles	627	1.0	6.4	302	634	123	3,956	1.6	1,585	46	132	111
Other	1,975	3.2	8.9	286	625	082	10,569	12	1,869	56	120	017
Other industries	812	1.3	6.6	179	756	107	1,677	19	1,736	39	31	115
Transport, communications, pub welfare	2,335	3.8	4.9	304	547	096	5,332	21	1,380	94	2	1700

Figure 2-2-2-2 Trends in R&D Expenses, Researchers, Technology Trade in Private Industry, by Industry (FY 1986)

(2) Components

The following areas are very important at the leading edge of R&D being done on component-related high-tech products:

A) The development of such applications technologies as sensor technology and electronic control technology to cope with the demands for higher precision, higher speed, higher capacity, and higher reliability as products need to be made smaller and lighter. Included in this area are such components as servo motors, semiconductor lasers, CCDs, and hydraulic control valves.

B) The development of ultrahigh precision processing technologies to cope with the demands for smaller sizes, lighter weights, and higher precision. Included in this area are such components as servomotors and semiconductor memory elements.

(3) Finished Products, Systems

The following R&D tasks are being pursued in the area of high-tech finished products and systems:

A) Making products and systems more knowledgeable and intelligent.

B) The enhancement of software and other interface media between humans on the one hand and machines and systems on the other. One aspect of this entails research on human sensitivity, perception, and feeling.

C) Further advances in high-speed processing and improved output quality (color output, high-resolution output).

D) Promotion of unification of information processing and telecommunications as society becomes increasingly information oriented.

Also, as we seek higher performance in systems and products, new materials need to be developed in some cases (artificial kidneys, optical magnetic disks, copiers), while a deeper understanding of product manufacturing mechanisms is required in others (bioproducts).

Hence, when we examine the trends in R&D related to high-tech products, particularly as regards the leading edge of industrial technological R&D being done by private industry, although there are limits to what can be undertaken, we may say that the extent of R&D work being done at the basic research level is quite considerable.

2. Leading Edge of Main Industry R&D, Main Trends in Private Industry R&D

(1) Leading Edge of Main Industry R&D

We surveyed the trends in the most advanced R&D being done in the 19 industries noted in Figure 2-2-2-4. The complete results are given in Appendix 2-3 at the end of this volume. We wish here to analyze the R&D trends in only nine of these industries in which a major portion of the most important R&D on industrial technologies is being done (cf Figure 2-2-2-5). In attempting this analysis, we must consider some of the changes that are now happening in socioeconomic structures.

a) As markets become more international and domestic markets become more mature (as seen in the basic materials industries), there is a need for business operations to become more diversified, for new business fields to be pioneered, and for products to be made more highly functional and discriminating, particularly in fields where competition is intensifying with NIE production.
b) As living standards rise, market demand is becoming increasingly sophisticated and diversified, calling for the development of more creative and high-value-added products.
c) As society becomes older and more mature, there is an increasing need to enhance the interface between machines and systems on one hand and human beings on the other.

1. High-Tensile Steel

High-tensile steel is currently being used in bulldozers, power shovels, track-mounted cranes, automobiles, bridge beams, and building structures. The use of such steel must be widened by lowering cost and by enhancing such properties as weldability, corrosion resistance, wear resistance, and low-temperature toughness. High-tensile steel has conventionally been made by adding such expensive alloying elements as nickel, chromium, and molybdenum. R&D work is now being done, however, on special heat-treating processes called controlled-cooling rolling which make it possible to control the crystalline structures n metal sand thereby enhance their strength.

2. Amorphous Alloys

Implementation research is being done on steel-core materials made of Fe-Si-β alloys which have been stably amorphousized. Amorphous alloys exhibit outstanding properties as high-magnetic-permeability materials, and are superior to conventional materials when used as high-strength or corrosion-resistant materials. Work is moving ahead on practical applications in this area, and demand is expected to grow in the future for a wide range of applications. Accordingly, R&D work is being done on high-flux-density materials and thin-film technologies.

3. Superconductors

R&D on metallic superconductors is being done in such applications areas as the linear motor car, superconductor generators, MRI, and Josephson elements.

4. Fine Ceramics

Compared to conventional ceramics (porcelain, glass, etc.), fine ceramics are characterized by highly pure raw materials and sophisticated manufacturing processes. Important to this field are the fine granulation of the raw material powder and achieving higher purities, better molding, processing, and bonding methods, and more reliable evaluation techniques. These efforts are leading to the development of highly reliable and uniform materials. R&D is also being done to overcome the perennial problem of brittleness in ceramic materials.

Most of the applications fields are currently concentrated in the area of electronic-component materials. As mechanical properties are improved, however, these materials will probably be used more in aircraft, space, and atomic energy, and as highly heat-resistant structural materials in various kinds of heat engines. Their use in the sliding parts in machine tools is also contemplated because of their high rigidity and wear resistance.

Figure 2-2-2-3 Trends in Most Advanced R&D on High-Tech Products

[figure continued]

[Continuation of Figure 2-2-2-3]

5. New Glass

The manufacturing methods and processing techniques used in the field of new glass are difficult because of the high levels of control required in chemical composition, purity, structure, and shape.

Such new techniques as new melting methods, sol-gel methods, CVD methods, vapor deposition methods, and sputtering methods are now being employed in vacuum or inert gas atmospheres. The glassification range has widened, moreover, through use of super-fast cooling methods. Thin-film, ultrafine pulverization, and spinning techniques are being employed in molding processes.

The most common applications for new glass today are in optical fibers, photomasks used in LSI production, and electronic functional materials of various kinds. As the electronics and optoelectronics industries grow in the future, however, the scope of new-glass applications is expected to expand rapidly and include such fields as ultralow-loss optical fiber, optical circuit elements, and organic materials. In this regard, further advances are being made in conventional technologies to improve the uniformity of coating films, for example. New glass compositions are being developed and R&D work is being done on revolutionary manufacturing techniques.

6. Polymer Separation Films

Polymer (or macromolecule) separation films are currently being used to separate aqueous solutions (seawater, blood, food products, sewage, etc.) and in gas separation applications (air, hydrogen-containing gases, etc.). In order to widen the market for these films, however, pioneer R&D needs to be done in the field of nonaqueous solution separation (synthetic chemical products, petrochemicals, etc.).

To that end, R&D work is being done to elucidate the separation mechanisms, to enhance the separating ability by selecting the ideal materials, and to increase the useful life of the films.

7. Engineering Plastics

Engineering plastics exhibit outstanding wear resistance and heat resistance and are being used to replace metals in a widening range of applications fields including electromechanical and electronic devices and automobiles. The properties of these materials need to be improved even more (making them lighter and stronger, for example) so that they can be used more widely (in aircraft and space structures, etc.).

To that end, R&D work is being done to enhance the moldability of existing engineering plastics, to develop highly moldable crystalline polymers, to develop super engineering plastics that exhibit phenomenal heat resistance, to achieve higher strength and rigidity using glass and carbon fiber fillers, and to develop polymer alloys which combine the characteristics of multiple resin types.

[figure continued]

[Continuation of Figure 2-2-2-3]

8. Composite Materials

The advantage of making composite materials is that it yields lightweight materials that are extremely strong. The levels of heat resistance currently being achieved are 250°C in FRP (fiber-reinforced plastics) and 450°C in aluminum-matrix FRM (fiber-reinforced metals). In order to raise these levels higher, we must develop heat-resistant matrices and fibers, and enhance the boundary compatibility between fiber and matrix. We must also raise the compounding and molding technologies to higher levels.

The range of applications is wide, thanks to the high strength-to-weight ratios of composite materials, and covers the aerospace, automotive, and consumer-products (sports equipment, bicycles, etc.) fields.

9. Optical Fiber

Research is moving ahead currently to develop the optimal structure of a 1.5-μm band, zero-dispersion, single-mode optical fiber for transmitting large volumes of information over long distances in the field of public communications. (Compared to currently used 1.3-μm wavelength fiber, this will facilitate lengthening relay distances and reducing transmission loss.)

10. Semiconductor Lasers

In order to enhance the performance of the DFB (distributed feedback) lasers now being used as major components in optical communications systems, work is being done to achieve higher output and higher speed. In the field of optical disk lasers, 30-mW class devices are being developed which have more uniform characteristics and higher yield, and high-output lasers are being developed in the 50-mW and higher classes. The OEIC (optical electronic integrated circuit) is also being developed to further enhance laser performance. The R&D work being done in the OEIC field includes research on low-power-consumption lasers and dry-etching end-face molding techniques.

11. CCD (Charge-Coupled Device)

There is a demand for larger numbers of pixels on display screens for enhanced resolution. The level currently is up to about 400,000 pixels, but R&D is being done at the 600,000-pixel level through the use of miniature pattern processing technology. R&D work is also being done to raise the S/N ratio in the interest of higher sensitivity. To enhance the signal (S), the lens effect and numerical aperture are being improved. To reduce noise (N), noise-disposal techniques are being developed.

[figure continued]

[Continuation of Figure 2-2-2-3]

12. Semiconductor Memory Elements

In the DRAM field, the 1M DRAM (access time = approximate 80 nsec, wire width = approximate 1.2 μm) is at the mass production stage. As capacities become larger, three-dimensional cell structures are being implemented using stacked-capacitor and trench configurations. As processor performance rises, faster memory elements are being demanded, and CMOS and Bi-CMOS technologies are being employed to meet this demand.

With a view to the 64M device, R&D work is being done on miniature processing techniques at the 1/4-μm scale using three-dimensional wiring and trench structures, and on the optimal design of ultraminiature transistors.

13. Microprocessors

As the number of transistors implemented on a single chip skyrockets, intense work is being done to develop such CAD applications as automatic layout wiring and automatic logic synthesizing tools and to develop design techniques using engineering workstations (EWSs). Much R&D work is also being done on RISC (reduced instruction set computer) microprocessors in the interest of better performance/cost ratios. General-purpose microprocessors that feature RISC architecture are now being developed as marketable products.

14. Bore Screws

Bore screws are critical components of machine tools which determine the precision of the shaft feed, and work is being done to achieve high-speed, high-precision feeding.

In this area, research priority is being placed on the development of high-precision machining techniques for thread grooves, heat-dissipation techniques, and new materials (ceramics, titanium) for bore screws.

15. Servo Motors

Servo motors are used as small precision drive motors in such OA equipment as floppy disk drives, hard disk drives, and printers. They are also used as small control motors in such FA equipment as industrial robots and NC machine tools.

Servo motors are made up of a main motor unit, a detection unit, and a control unit. As electric servo technology and electronics have advanced, however, functionality, miniaturization, and cost-effectiveness which could not be realized in the past can now be realized. The demand for these motors is growing rapidly in conjunction with the higher performance of the main motor units.

Future demand is likely to be for even greater sophistication, smaller sizes, lighter weights, and better cost-effectiveness. To meet these demands, R&D work is being done to increase motor power density, develop better detector units, and improve control devices.

[figure continued]

[Continuation of Figure 2-2-2-3]

16. Hydraulic Control Valves

Hydraulic control valves are highly valued for their functioning as means for controlling the transmission of power. Nevertheless, as greater energy efficiencies, high-tech implementations, and computer controls are demanded in the host device or system, the instability in performance which arises from using a fluid as the transmission medium is undoubtedly becoming a problem. In order to reduce the effects of viscosity changes in hydraulic fluids due to fluid temperature changes, and to improve reproducibility and stability, combined use is being made of sensor technology, electronic control technology, and computer technology. These efforts should result in enhanced precision and reliability.

17. Optical-Magnetic Disks

The optical-magnetic disk makes it possible to write data to a high-density storage disk. It is expected that such disks will be used to store analog videofiles and digital document files, and also used as a computer storage medium.

Advances still need to be made in terms of achieving improved weather resistance and durability in optical-magnetic disks, as well as higher densities and faster access speeds. To that end, work is being done to develop better storage materials and to develop storage techniques suitable to such storage materials.

18. 1/2-Inch Home VCR

As the home VCR has proliferated, new demands are tending in two directions, namely in the direction 1) of demand for simpler functionality and user-friendliness, and 2) of demand for higher picture quality.

With the use of metal tapes as seen in the S-VHS and ED beta systems, and the development of signal processing systems and magnetic head machining techniques, there has been a trend toward using higher bands and employing I/C separation techniques, and, when connected to TV sets equipped with an S terminal, the picture quality has now become almost as good as broadcast TV picture quality. R&D work is being done to achieve compatibility with EDTV ("clearvision") systems.

19. Computers

As the trend toward more powerful, low-cost general-purpose processors has accelerated, we have reached the era of the tabletop computer which performs at the same level as the large mainframes of 10 years ago. In terms of higher performance, very rapid advances are being made in achieving higher speeds in supercomputers, which are being used in an ever-widening range of fields.

To cope with networking advances and the increasing numbers of those employing networks, R&D work is being pushed ahead to improve

[figure continued]

interconnection techniques and enhance decentralized processing. Avid research is also being done in the area of man-machine interfaces, and much R&D work is being focused on improving software production efficiency and transportability.

In the area of processing intellectual information, R&D work is moving ahead in AI (artificial intelligence), expert systems, and parallel processing.

20. Databases

In order to enhance the utility of databases and encourage their wider use, intense R&D efforts are being made in such AI-related fields as pattern recognition, natural language analysis, vague data processing, and HI (human interface), as well as in the area of gateway connections.

21. CAD/CAM

CIM (computer integrated manufacturing) is now being more widely implemented, employing computers in the R&D, production, and marketing stages. The computer technology used in the design and manufacturing stages is predominantly CAD/CAM (computer aided design/computer aided manufacturing).

Current R&D in the CAD/CAM area includes design theory and graphics input/output technology aimed at making CAD/CAM more intelligent.

22. Copiers

Digital technology is being employed to make advances in full-color and composite implementation and in systemization.

In order to develop new products, R&D work is being done on new materials in the field of organic semiconductor technology. Other R&D efforts are being made to achieve smaller, lighter copiers for the purpose of expanding the copier market beyond the office and into the home.

23. D-PBX

D-PBX (digital PBX) may be defined most simply as "computerized PBX." It is now possible to connect telephone lines (ordinarily used for voice transmission) to computer terminals or LANs (local area networks) in order to exchange data via digital signals. Hence, the D-PBX is now positioned as a central unit in a company's internal communication system. Advanced decentralized processing functions now make it possible to redistribute processing loads among multiple processors, and R&D work is being done on new service functions (voice-mail, media conversion, etc.).

With the opening of NTTs 64-service INS network (April 1988), R&D work in an ISDN-compatible D-PBX has intensified.

[figure continued]

[Continuation of Figure 2-2-2-3]

24. Assembly Robots

The market for industrial robots has grown tenfold in the past 10 years. Robots are a major tool of FA and are used extensively in assembly processes in the manufacturing industries. Current R&D in robotics is focused on sophisticated robot visual and tactiles, sophisticated manipulation techniques (for miniature-scale, high-precision manufacture), and artificial intelligence. It is hoped that these efforts will result in further automation in the manufacturing industries, and applications in the nonmanufacturing industries (construction, space).

25. Laser Machining

Laser machining is characterized by high output, light condensation, and controllability, and has become a major tool and technology in FMS and FA.

R&D priorities in the industrial laser field include the improvement of laser generators (higher-stability oscillation, higher output) and enhancements in the laser machining systems (improving the reliability of the optical system, etc.).

26. Laser Printers

Laser printers were developed as high-speed output devices for general-purpose computers. As applications have widened into desktop publishing and CAD, however, R&D has been moving ahead in higher-speed printing, higher resolution, multimedia compatibility, and color printing.

R&D is moving ahead in standardizing the interface between fonts and application software and in perfecting a Japanese-language page-writing language based on Postscript (a language designed for printing). Efforts are also being made to reduce purchase and running costs.

27. Accelerators

Accelerators are expected in the future to be used in a wider range of fields, including the creation of new substances, improving materials, superminiature processing, lithography, microvolumetric analysis, and biotechnology.

This will require practical accelerators to meet the diverse needs of these applications. Priority is being given in R&D to the development of small SOR, the development of superconductor electromagnets, the generation and control of high-current electron beams, and the development of powerful high-energy proton beams.

28. Spectrum Analyzers

Spectrum analyzers have built-in tracking generators for sweeping frequencies and screens for displaying waveforms. It is hoped that these components can be utilized in performing functions other than conventional waveform analysis in integrated measuring devices. [figure continued]

[Continuation of Figure 2-2-2-3]
[Continuation of Spectrum Analyzers]

More specifically, it is now possible to build a network analyzer which can measure such complex transmission characteristics as line phase, delay times, and various other parameters. It is also possible to display and measure radio-frequency impedances on a Smith chart (a set of polar coordinates on which phases and amplitudes are displayed) shown on a CRT.

R&D work is also being done in the field of automatic measurement using GPIB standard units and on sophisticated functions for displaying digital data on CRTs.

29. Aircraft Engines

As more powerful engines are being developed for larger and larger passenger aircraft, new types of engines are also being developed which enhance overall fuel economy, lower service costs and life-cycle costs, and reduce noise. In the field of turboprop and turboshaft engines, a new generation of innovative models are being developed which have fewer moving parts and consume less fuel. In the field of military aircraft, new models are being developed (for service delivery in the mid 1990s) in America and Europe which are much lighter and are higher in performance. In the meantime, the standard engines are being improved in stages.

30. MRI

MRI R&D is moving ahead on various types of magnets for generating strong static magnetic fields. These R&D efforts are very comprehensive, covering such aspects as picture quality, equipment and installation costs, and maintenance costs. Research is also being done on ways to create images more quickly, and thereby overcome the serious MRI shortcoming of long exposure times. Overcoming this problem is critical to making this expensive product more economical. Other R&D work is focusing on three-dimensional displays of blood-flow imaging and multilayer scanning data.

31. Artificial Kidneys

Dialysis is the mainstay of artificial kidneys, but filtration and adhesion methods are also being used to augment dialysis. Advances need to be made in the technologies of polymer materials and hollow yarn spinning as used in dialyzers. Toward that end, R&D is being done on thin film, organic compatibility, and the elimination of specific substances from the body. Other research is focusing on improving the performance of artificial kidneys, and making them smaller and more intelligent.

32-34. Bio Products

So far, in the field of biotechnology, R&D efforts have expanded rapidly in such micro areas as DNA sequences. In terms of the complex functions that are native to living organisms, however, these continue to be used as "black boxes."

[figure continued]

[Continuation of Figure 2-2-2-3]
[Continuation of Bio Products]

In order to understand such biological functions as substance conversion functions and information apprehension functions, and use these efficiently in industrial applications, greater importance is being given to more basic research areas such as protein engineering, organic function utilization technology, and chromosome engineering. Interest has also intensified in biotechnological applications in the field of marine biology, which is a new frontier in biotechnology.

35. Light Water Reactors

Work is moving ahead on the implementation of improved light water reactors which have resulted from a national light water reactor improvement and standardization program. R&D is focusing on high-performance fuels designed for extended-cycle operation and hence greater economy, and on sophisticated security and safety systems for the reactors themselves, with a dual emphasis on reliability and economy.

36. Solar Power Generation

Developmental work is being done on element technologies for new types of solar cells (including the thin solar cell) with the objective of achieving solar power generation technology which will be cost-competitive with conventional power generation.

37. Satellite Launch Rockets

The LE-5 liquid oxygen/liquid hydrogen engine, the development of which was based completely on Japanese technology, is used as the second-stage engine in the H-I rocket which is currently Japan's main satellite launch vehicle. The focus of current R&D is on larger payload capacity and lower costs. Other R&D work is being done on such air-breathing engines as the scramjet for use in spaceplanes.

38. Communications Satellites

As the demand for satellite communications grows, communications satellites need to be made larger and able to support more channels. To this end, R&D is moving ahead on implementing mission equipment through the use of monolithic microwave integration. Research and development is also being done on two-liquid thrust systems, triaxial control of large satellites, and enhanced radiation-resistance in integrated circuits, all aimed at making satellite common bus technology more sophisticated.

39. Oceangoing Structures

In recent years, petroleum prospecting and development efforts have expanded to deeper ocean areas and to smaller oil fields. These trends are making the conventional jacket-type platform more expensive to operate.

[figure continued]

[Continuation of Figure 2-2-2-3]
[Continuation of Oceangoing Structures]

Accordingly, R&D work is being done on platforms which can operate more economically at great ocean depths, namely the guide-tower platform (for depths of 200~500 meters) and the tension-leg platform (for depths greater than 500 meters).

40. Super-High-Rise Buildings

Research and development in this field is extremely diverse, ranging from such "hard" areas as building techniques (improved RD, combined SRC and S, etc.) and materials (high-strength, superdurable) to such "soft" areas as space design for enhanced livability and research on the physiological and psychological effects of high-rise living. More emphasis is recently being given to sway-control technology. In buildings of 60 stories or more, the swaying caused by wind is now thought to be a more acute problem than the earthquake threat. Research is being done on active control methods in which wind-induced sway is sensed and actively counteracted under computer control. The efficient transport of people and other movables is the goal of R&D on high-capacity elevators and transporting trash through pipes.

In response to these socioeconomic changes, companies are staking their very existence on the success of investing their managerial resources in research and development. While R&D is becoming more multifaceted and greater emphasis is given to basic research, companies are moving aggressively to engage in joint R&D projects with other companies, including domestic and foreign companies in different industries.

(1) Steel Industry

A) The stronger yen is reducing Japanese price-competitiveness in international markets, while Japan is being flooded with cheap imported materials. In this difficult context, higher-value-added products are being developed to cope with increasingly sophisticated and diverse industrial demand. These products include surface-processed steel plate and high-tension steel.

B) In the interest of medium- and long-term growth, the steel industry is upgrading its product mixes and gearing up for more efficiently producing fine steels and other products in small lots. The industry is also doing R&D work on enhancing its production processes through the use of artificial intelligence. Basic and revolutionary research is also being carried on in such areas as semi-solidification processes and fusion-reduction technology.

C) The steel industry is also using its vast know-how in conventional technology to move into new business areas such as new materials. Examples of such R&D areas into which the industry is moving are carbon fiber and fine ceramics based on coke-furnace technology, titanium and silicon semiconductors based on secondary refining technology, amorphous alloys based on casting technology, and crystallization-controlled metallic materials (magnetic materials) based on rolling technology.

Agriculture, Forestry, Fisheries
Minerals & Mining
Construction
Manufacturing Industries
  Food Products
  Textiles
  Pulp, Paper
  Printing, Publishing
  Chemical Industries
    General, Chemical Fibers
    Oils, Paints, Coatings
    Pharmaceuticals
    Other Chemical Industries
  Oil & Coal Products
  Plastics
  Rubber
  Ceramics
  Steel
  Nonferrous Metals
  Metal Products
  Machinery
  Electrical Equipment
    Electric Machines & Tools
    Communications, Electronics,
      Electric Measuring Equipment
  Transport Equipment
    Automobiles
    Other Transport Equipment
  Precision Machinery
  Other Manufacturing Industries
Transport, Communications, Public-
  Service Industries

(1) Basic Material Industries
  1) Steel
  2) Chemicals
  3) Other Basic Material Industries
    <1> Nonferrous metals
    <2> Ceramics, Quarrying
    <3> Oil, Coal Products (Oil Refining
(2) Process & Assembly Industries
  1) General Machinery Industries
    <1> Metal Machine Tools
    <2> Business Machines
  2) Electrical Equipment
  3) Automobiles
  4) Other Machinery Industries
    <1> Cameras
    <2> Watches and Clocks
(3) Consumer-Related Industries
  1) Textiles
  2) Other Consumer-Related Industries
    <1> Paper, Pulp
    <2> Printing
(4) Minerals and Mining
    <1> Oil Development
    <2> Coal
    <3> Copper, Zinc, Tin
(5) Public Services
    <1> Electricity
    <2> City Gas

(Industrial Classifications R&D Survey (General Affairs Agency))
Note: Standard Industrial Classifications have been altered.

"Progress of Structural Adjustment and Outlook for Future Industrial Structure" (December 1987, Planning Subcommittee, Industrial Structure Council) Both were classified.

Figure 2-2-2-4 Main Industries (19) Surveyed in Technology Study

D) Against this background, with a declining trend in capital investment and a low ratio of R&D expense to sales of 2.5 percent (FY 1986), which is even lower than the 3 percent average of all manufacturing industries, actual R&D expenditure has grown 2.5 times in the past 10 years. The number of employees engaged in R&D activity has also increased, with more researchers now working in such nonsteel areas as new materials and electronics.

E) When we examine technology transfers and acquisitions, we find that the steel industry is transferring a lot of technology overseas, which is an indication of the levels to which Japanese steel technology has been raised.

(2) Chemical Industry

A) Japan's chemical industry is structurally centered on internal demand, and is expected to continue to exhibit steady growth in the future supported by relatively strong internal demand. The growth in demand is being fired mainly by engineering plastics, pharmaceuticals, surfactants, electronic materials, and other fine chemicals. In product fields such as general-purpose resins (polyethylene, vinyl chloride, etc.), development among the NIEs is expected to result in stiffer competition, so the trend here is toward finer and more specialized chemical products.

B) In the chemical industry, technology has made it possible to control molecular and atomic structures, which has resulted in broader applications in such fields as new materials, electronics, and biotechnology. By more exactly controlling the degree of polymerization and molecular weight distribution in synthetic resins, for example, these resins are being made vastly more functional. The control of molecular and crystalline structures is leading to new electrical conductors and high-crystalline materials. Molecular design is making it possible to develop more effective pharmaceuticals. Genetic engineering recombinant DNA technology) is able to impart new functions to cells. This R&D is extremely diverse.

C) The chemical industry has always invested heavily in research and development. In view of the developments discussed above, however, R&D investment is being increased further. In FY 1986, the ratio of R&D expense to sales was 4.3 percent in this industry, second only to the 5.5 percent of the electrical equipment industry. In actual terms, chemical R&D expenditure has nearly tripled in the past 10 years. A rapidly widening segment of R&D funding, moreover, is being allocated to basic research, with the percentage increasing to 11.5 percent in 1986, the highest among the manufacturing industries (manufacturing industry mean = 6.1 percent). In the past few years a considerable number of chemical companies have built research laboratories dedicated primarily to basic research. Some of these laboratories are located overseas.

D) The number of researchers continues to grow year after year. By this measure, the chemical industry ranks second behind the electrical equipment industry. When we examine the fields in which these researchers are specializing, we find that an increasing proportion of them are doing work in nonchemical fields such as biology, agriculture, and electronic devices.

E) As chemical product markets become more and more international, we are seeing more examples of joint ventures and joint research projects with foreign chemical companies with which Japanese companies enjoy a complementary relationship in terms of both markets and technology. Looking at international technology exchange in the chemical industry overall, technology is being transferred out on roughly the same scale as it is being transferred in.

(3) Nonferrous Metals

A) In the nonferrous metals industry (nonferrous metal products manufacturing, electrical cable manufacturing), although there are differences among various segments of the industry, demand is maturing, exports are declining, and imports are increasing. R&D activity, accordingly, is being intensified in the field of new materials.

B) In the nonferrous metal products manufacturing segment of the industry, development work is moving ahead in such areas as organically compatible materials employing titanium and rare earth metals, optical/magnetic memory media, and shape-memory alloys. This R&D work is built upon the foundation of refining technologies developed for producing superpure products and on the technological know-how which has been built up in the pursuit of new metallic properties.

C) In the electrical cable manufacturing segment, R&D is moving ahead on superconductors in the search for low-resistance, low-loss (or no-loss) wire and on optical fiber cable which can meet the demand for higher-capacity communications cable.

D) In this manner, R&D efforts are intensifying in the nonferrous metals industry. Despite the sluggishness of sales over the past several years, R&D expenditure in the industry has grown at an annual rate of 10 percent or higher for the past 3 years.

E) The number of researchers is also increasing gradually, but there are not enough researchers in the superconductor field (in which the nonferrous metals industry is placing extremely high priority), and it will be difficult for the industry to acquire the researchers needed in that field.

(4) Ceramics, Quarrying Industries

A) Among the ceramics and quarrying industries is the cement industry, which has seen a resurgence in domestic demand which had stagnated after the second oil shock. This industry continues to face serious difficulties, however, due to a decline in the number of cement users and the influx of cheaper products from neighboring NIEs. The glassmaking industry, meanwhile, has enjoyed steady growth in domestic demand, and is in a relatively stable condition.

B) Faced with those market conditions, the cement product manufacturers are now building upon their accumulated know-how by doing R&D in fine ceramic raw material powder manufacturing, structural materials, and electronic materials. They are also working hard to develop high-purity silicon products and dental and orthopedic prosthetics. Glassmakers are working to develop such higher-value-added products as reinforced glass and heat absorbing/reflecting glass, and doing R&D work in the field of fiber optics.

C) It is reflective of these developments that the industry is now increasing its R&D investments, in terms of capital and human resources, even though sales growth has been sluggish.

(5) General Machinery Industries

A) The general machinery industries include the manufacture of metal machining equipment, office machines, and other machines for use in civil engineering, construction, chemicals, and textiles. This industry is a basic supporting industry in that it provides the production and system technologies for other manufacturing industries. As a consequence, this industry is very sensitive in capital investment trends and other economic variables.

B) Current R&D focuses in this industry include R&D efforts to cope with increasingly sophisticated user demand and continual advances in implementing FMS (flexible manufacturing systems), FA, and OA. Complex, integrated systems are being developed, and R&D work is moving ahead in super-microprocessing techniques and on CIM (computer integrated manufacturing) software.

C) In the general machinery industries, aggressive R&D work is being done to upgrade production and systems technologies in order to keep abreast of new applications of information technology, enhanced machining/processing precision, and new materials processing.

D) Reflective of the situation outlined above, R&D investment in the general machinery industries has grown relatively steadily, except for the aberrations caused in 1986 by the strong yen. The intensity of this R&D work does vary considerably, however, from one specific industry to another. The level of R&D activity in the metal machining equipment manufacturing industry continues to be low, for example, while the level in the business machine industry is high. Increases in basic research funding is being supported mainly by growth in the business machine field, which is also the field in which most of the increases in the number of researchers are occurring.

E) Incoming technology transfers far outstrip outgoing transfers, a trend that is particularly pronounced in the nonbusiness-machine industries.

F) Some new research facilities are being built, mainly among the business machine manufacturers.

(6) Electrical Equipment

A) The electrical equipment industries include manufacturers of such home electronics equipment as VCRs and CD players, such industrial electronics hardware as computers and communications gear, and such electronics components as semiconductor devices. Supported by high demand growth for these products, production growth during the 9 years from 1975 to 1984 averaged 17.5 percent a year (based on 1980 prices).

B) In recent years, however, profits in this industry from exports have deteriorated due to the strong yen, trade friction has intensified, and the competition of Asian NIEs in Western markets has become a serious problem.

In response to these pressures, more of these products are now being manufactured in overseas factories, international relationships are being forged between domestic and foreign companies, efforts are being made to cultivate domestic demand and thus reduce export dependence, and a division of labor with the NIEs is being promoted.

C) The effects of these developments in the international marketplace are also being seen in research and development. In the consumer electronics industry, R&D is being done on high-quality television, ultrathin television, high-resolution VCR, home-control telephones, automatic air-conditioning systems, integrated home security systems, and other HA (home automation) related fields which are oriented toward domestic demand and higher-value-added products. In the industrial electronics industry, advanced research is being done on superhigh-speed computers, artificial intelligence, and the neurocomputer. At the same time, R&D is moving ahead to promote the merging of data processing and telecommunications in, for example, achieving interoperability between computer networks, and in such user-oriented areas as the man-machine interface.

D) In the electronics component industry, much R&D work is being done in response to the developments in the consumer and industrial electronics industries discussed above. This includes the development of new electronic materials such as photoreactive materials, the development of new functional devices such as superlattice elements, and the development of technologies to support larger capacities, higher speeds, and denser integration.

E) In the electrical equipment industries, total R&D expenditures amount to roughly ¥2 trillion a year (the highest of any industry group). This R&D is carried on by approximately 90,000 researchers. However, more than 95 percent of these resources is allocated to applications and developmental research, with little left over for basic research. Outgoing technology transfers, meanwhile, outweigh incoming transfers.

(7) Automobile Industry

A) Since 1980, Japan has produced more automobiles than any other country in the world. The Japanese automobile industry now accounts for nearly 30 percent of all automobile production in the world. Since the fall of 1985, however, exports have been decreasing due to the strengthening yen. The export environment has also changed, with voluntary restrictions placed on passenger automobiles exported to the United States and the implementation of monitoring policies with regard to exports to the common market. This has resulted in an active transition to a more global production structure in which almost all Japanese automakers have set up factories in North America. Some of the assembled cars and parts made in these factories are imported back to Japan.

B) Technological R&D is being done to respond to increasingly sophisticated and diversified user needs, to employ new materials and electronics to better effect, to improve designs, and to make automobiles which can be more easily accommodated in limited Japanese home parking facilities. The ultimate objective of these efforts is to stimulate demand.

C) To achieve its R&D goals, the automobile industry has increased its R&D expenditures more than 10 percent a year for the past 10 years. Its R&D expenditure per researcher is the highest of any industry in Japan.

D) The proportion of basic research being funded is not very high, but basic research is being carried on in new materials, fine ceramic sensors, and fine ceramic structural components for engines.

E) More technology is now being exported than is being imported, partly as a result of the extensive overseas operations.

(8) Textile Industry

A) The textile industry is in an extremely difficult situation, faced with declining demand for exports to China, East Asia, and the Middle East, deteriorating export profits, and increasing competition from the NIEs. Efforts to dispose of excess plants and equipment and make other structural adjustments continue, as well as those to move successfully into new industrial fields.

B) Using their know-how in the textile field, some textile manufacturers are now developing carbon fibers and new functional polymer fibers. Research is also being done on artificial organs and skin in which the minute structural properties of fibers are being utilized.

C) Other efforts are being directed in more conventional textile fields to develop better fitting, more comfortable, and more discriminating new fabrics. This R&D work is making use of such sophisticated technology as three-dimensional CAD.

D) R&D activity in the textile industry as a whole is somewhat sluggish, but some R&D work is being done, focusing on such new and budding technologies as those noted above, in the interest of product enhancement and business diversification.

(9) Paper and Pulp Industry

A) As a result of sluggish demand in the wake of the second oil shock, structural modifications were pursued in the paper and pulp industry, including a reduction in plant capacity. Production activity in this industry is now brisk, however, as a result of the recovery in domestic demand.

B) The paper and pulp industry is now engaged in R&D in such areas as energy conservation, paper recycling technology, and improved paper quality. Basic research is also going on to improve products in which biotechnology is being applied.

C) The level of R&D activity is low (ratio of R&D expenditure to sales = 0.8 percent) compared to other industries, but the level is rising slowly, including some areas of basic research.

Steel Industry

	FY 1986	FY 1986
(A) R&D expenditure (x ¥100 million)	998	2,553
(B) Ratio of R&D expenditure to sales (percent)	1.01	2.53
(C) Ratio of R&D expenditure to capital investment "	7.6	31.9
(D) Basic research portion of R&D expenditure "	6.8	6.0
(E) Employees involved in research (x 100)	111	140
(F) Percentage of total employees	3.0	5.0
(G) Percentage of R&D investment in other fields	24*	49

*FY 1975

(H) Research facility construction starts
March 1983 or earlier: 28
April 1983 or later: 7

(A)-(D)

R&D Investment

- While capital investment has exhibited a declining trend, R&D investment has doubled over the past 10 years.

Basic Research

- Research is being done in such new-materials fields as carbon fiber, fine ceramics, titanium, silicon semiconductors, and amorphous alloys, and in semi-solidification processes, fusion-reduction steelmaking techniques, and the implementation of Al technology.

(E)-(F)

- While the total number of employees declined, the number of researchers exhibited an increasing trend.
- There was a particularly noticeable increase in researchers in the new-materials and electronics fields, reflecting efforts to diversify.

(G)

- The application of information technology to manufacturing processes proceeded at a rapid rate.
- R&D advances are being made in such new-materials fields as new metallic materials, fine ceramics, and composite materials, and cross-field technological cooperation is moving ahead.

(H)

- New facilities are being established for semiconductor and new-materials research.

Figure 2-2-2-5 Technological Development Trends at Leading Edge in Main Industrial Fields [Commentary keyed to preceding numerical data]

[figure continued]

[Continuation of Figure 2-2-2-5]

Chemical Industry

		FY 1976	FY 1986
(A) R&D expenditure (x ¥100 million)		3,519	9,836
(B) Ratio of R&D expenditure to sales	(percent)	2.4	4.3
(C) Ratio of R&D expenditure to capital investment	"	42.3	72.8
(D) Basic research portion of R&D expenditure	"	8.9	11.5
(E) Employees involved in research (x 100)		604	799
(F) Percentage of total employees		10.3	14.8
(G) Percentage of R&D investment in other fields		7*	9

*FY 1975

(H) Research facility construction starts
March 1983 or earlier: 164
April 1983 or later: 36

(A)-(D)

R&D Investment

• This industry is second only to the electrical equipment industry in the ratio of R&D expenditure to sales. The chemical industries which are beefing up their R&D efforts have increased R&D expenditure nearly threefold in the past 10 years.

Basic Research

• As the industry moves in the direction of fine and specialty chemicals, structural control at the atomic and molecular levels becomes increasingly necessary. This is leading to basic research in a wider range of fields than before. This industry is now the leader in terms of the proportion of total R&D funding allocated to basic research.

(E)-(F)

• The number of researchers increases year after year. This industry has one of the highest ratios of researchers to total employees of any industry.
In recent years, the number of researchers has increased particularly in such nonchemical areas as biology, agriculture, mechanics, and electronics.

(G)

• Emphasis is being given to bio fields and efforts are being made to expand into the semiconductor and electronics field.

(H)

• Construction work is moving ahead on basic research facilities that will provide centers for advanced technological development. Foreign-backed manufacturers are aggressively building facilities to carry on product development research.

[figure continued]

[Continuation of Figure 2-2-2-5]

Nonferrous Metals

		FY 1976	FY 1986
(A) R&D expenditure (x ¥100 million)		286	1,102
(B) Ratio of R&D expenditure to sales	(percent)	1.0	2.1
(C) Ratio of R&D expenditure to capital investment	"	20.4	39.2
(D) Basic research portion of R&D expenditure	"	4.5	4.5
(E) Employees involved in research (x 100)		40	78
(F) Percentage of total employees		4.0	6.2
(G) Percentage of R&D investment in other fields		24*	57

*FY 1975

(H) Research facility construction starts
March 1983 or earlier: 21
April 1983 or later: 17

(A)-(D)

R&D Investment

- Sharp increases are being made in R&D investment. R&D expenditure has increased at an annual rate of 10 percent or more over the past 3 years despite the sluggishness of sales.

Basic Research

Avid basic research efforts are being made in fiber optics, superconductors, shape memory alloys, and intermetallic compounds.

(E)-(F)

- Despite a decline in total employees, the number of researchers is exhibiting an increasing trend.
- The demand for researchers is particularly acute in the superconductor field, a demand which is not being adequately met.

(G)

- Cross-field research is going on in such new-materials areas as shape-memory alloys and optical-magnetic recording materials.

(H)

- Research is moving ahead in such areas as Ga and As crystalline compound semiconductors, solid laser materials, fiber optics, and other materials related to optical communications systems.

[figure continued]

[Continuation of Figure 2-2-2-5]

Ceramics, Quarrying

		FY 1976	FY 1986
(A) R&D expenditure (x ¥100 million)		521	1,876
(B) Ratio of R&D expenditure to sales	(percent)	1.4	2.9
(C) Ratio of R&D expenditure to capital investment	"	31.1	48.0
(D) Basic research portion of R&D expenditure	"	4.0	7.2
(E) Employees involved in research (x 100)		95	146
(F) Percentage of total employees		3.9	6.9
(G) Percentage of R&D investment in other fields		38*	47

*FY 1975

(H) Research facility construction starts
March 1983 or earlier: 24
April 1983 or later: 8

(A)-(D)

R&D Investment

- While sales growth has been sluggish due to the necessity of developing new business areas, R&D expenditure has been steadily rising.

Basic Research

More basic research is being done in such new-materials fields as fine ceramics, high-purity silicon, dental and orthopedic prosthetics, and new glass.

(E)-(F)

- While the total number of employees is declining, the number of researchers is increasing.
- The demand is particularly high for researchers in the fields of electronics and fine ceramics.

(G)

- Cross-field research is being done in electronics in the optical materials field and in structural material technology in the fine ceramics field.

(H)

- Basic research facilities are being constructed for developmental work in the fields of ceramics, fiber optics, and superconductors.

[figure continued

[Continuation of Figure 2-2-2-5]

General Machinery

		FY 1976	FY 1986
(A) R&D expenditure (x ¥100 million)		1,386	3,791
(B) Ratio of R&D expenditure to sales	(percent)	1.7	2.8
(C) Ratio of R&D expenditure to capital investment	"	61.6	87.5
(D) Basic research portion of R&D expenditure	"	1.6	4.5
(E) Employees involved in research (x 100)		218	332
(F) Percentage of total employees		4.3	6.6
(G) Percentage of R&D investment in other fields *FY 1975		22*	35

(H) Research facility construction starts
March 1983 or earlier: 43
April 1983 or later: 32

(A)-(D)

R&D Investment

- R&D expenditure is increasing, but the level of this expenditure as a percentage of sales is not very high, taking this industry group as a whole. Avid research work is being done, however, in the business machine manufacturing industry.
- The primary research focus is product development with emphasis on smaller sizes, higher quality, and multifunctionality.

Basic Research

- Basic research is not given very high priority, but some basic research is being done in semiconductor elements, AI technology, sensor technology, and digital technology (primarily in the business machine field). The goal of this research is to achieve greater functionality, reliability, and speed.
- Research is also moving ahead in ultraminiature process technology.

(E)-(F)

- The number of researchers in the business machine manufacturing industry is increasing every year.
- The demand for more researchers is particularly acute in the areas of software development, electronics, and artificial intelligence.

(G)

- Cross-field research is being done in electronics, communications, and software development.
- Other cross-field research is being done in materials technology.

(H)

- Facilities are being established for research in electronics and systems technology.

[figure continued]

[Continuation of Figure 2-2-2-5]

Electrical Equipment

		FY 1976	FY 1986
(A) R&D expenditure (x ¥100 million)		4,917	19,800
(B) Ratio of R&D expenditure to sales	(percent)	3.7	5.5
(C) Ratio of R&D expenditure to capital investment	"	104.4	94.4
(D) Basic research portion of R&D expenditure	"	4.4	4.1
(E) Employees involved in research (x 100)		847	1,518
(F) Percentage of total employees		9.5	13.4
(G) Percentage of R&D investment in other fields		11*	9

*FY 1975

(H) Research facility construction starts
March 1983 or earlier: 90
April 1983 or later: 64

(A)-(D)

R&D Investment

- R&D is being actively funded in such electronics areas as semiconductors.
- There was a sharp decline in the growth of R&D investment in FY 1986 (up only 2.2 percent from the previous year), however, due to the effects of the strong yen and demand sluggishness.
- The ratio of R&D investment to sales is high (5.5 percent).

Basic Research

- As compared to applications and developmental research, basic research overall is on the decline.
- The research themes most emphasized are superlattice elements, multielement semiconductors, biosensors, biochips, AI, and superconductors.

(E)-(F)

- The number of researchers is increasing every year.
- More people are being hired for research work in materials and biorelated fields.

(G)

- Applications of artificial intelligence and other areas of the social sciences are being made.
- Applications of biotechnology are beginning to be made.

(H)

- Some general research facilities are being built (including a few for basic research), but most of the new research facilities are for systems or product development.

[figure continued]

[Continuation of Figure 2-2-2-5]

Automobile Industry

		FY 1976	FY 1986
(A) R&D expenditure (x ¥100 million)		2,193	8,404
(B) Ratio of R&D expenditure to sales	(percent)	2.2	3.2
(C) Ratio of R&D expenditure to capital investment	"	37.9	50.8
(D) Basic research portion of R&D expenditure	"	4.6	4.8
(E) Employees involved in research (x 100)		360	548
(F) Percentage of total employees		5.6	10.8
(G) Percentage of R&D investment in other fields *FY 1975		12*	7

(H) Research facility construction starts
March 1983 or earlier: 26
April 1983 or later: 14

(A)-(D)

R&D Investment

- Most R&D geared toward new models. R&D expenditure has grown by 10 percent annually or better over the past 10 years, but has been flat for the past 5 years as a percentage of sales.

Basic Research

- Little priority is given to basic research, but joint research is being done in the new-materials (composites, ceramic sensors, components), and electronics fields.

(E)-(F)

- Research staffs are expanding, primarily in terms of technicians in the electronics field.

(G)

- Automobiles are being made more reliable and comfortable by utilizing electronics technology.

(H)

- Facilities are being created for general technological research.

[figure continued]

[Continuation of Figure 2-2-2-5]

Textile Industry

		FY 1976	FY 1986
(A) R&D expenditure (x ¥100 million)		209	627
(B) Ratio of R&D expenditure to sales	(percent)	0.65	1.23
(C) Ratio of R&D expenditure to capital investment	"	18.7	31.7
(D) Basic research portion of R&D expenditure	"	2.39	6.37
(E) Employees involved in research (x 100)		54	70
(F) Percentage of total employees		2.1	3.8
(G) Percentage of R&D investment in other fields *FY 1975		58*	71

(H) Research facility construction starts
March 1983 or earlier: 58
April 1983 or later: 7

(A)-(D)

R&D Investment

- There has been little or no growth in annual R&D expenditure over the past 5 years.

Basic Research

- There has been no growth in the funding of basic research over the past 5 years.
- Developmental work is being done on carbon fibers and new functional polymer fibers, as well as on improved fit and comfort through the use of three-dimensional CAD.

(E)-(F)

- The overall level of research personnel has remained roughly constant.

(G)

- Companies are moving into such new fields as polymer chemistry, biotechnology, and new materials.
- Cross-field R&D is being done in the area of mechatronics using CAD/CAM technology.

(H)

- In some companies basic research facilities are being upgraded to facilitate basic research in the biotech and artificial organ fields.

[figure continued]

[Continuation of Figure 2-2-2-5]

Paper and Pulp

		FY 1976	FY 1986
(A) R&D expenditure (x ¥100 million)		136	339
(B) Ratio of R&D expenditure to sales	(percent)	0.5	0.8
(C) Ratio of R&D expenditure to capital investment	"	6.1	8.0
(D) Basic research portion of R&D expenditure	"	4.4	5.0
(E) Employees involved in research (x 100)		33	34
(F) Percentage of total employees		2.1	3.8
(G) Percentage of R&D investment in other fields *FY 1975		21*	22

(H) Research facility construction starts
March 1983 or earlier: 22
April 1983 or later: 5

(A)-(D)

R&D Investment

- The level of R&D expenditure is low compared to other industries, although R&D investment is gradually increasing.

Basic Research

- Research has been started in the polymer and biotech fields.

(E)-(F)

- No appreciable growth.

(G)

- Moving ahead with applications of polymer chemistry and biotechnology.

(H)

- Most [new] research facilities are geared toward new product development.

Source: Prepared from the results of a survey commissioned by the Agency of Industrial Science and Technology and the "Scientific & Technological Research Survey Report" issued by the General Affairs Agency.

(2) Major Trends in Private Sector R&D

Thus far we have examined the R&D trends in the field of biotech products in particular and in major industries in general. We wish next to analyze a number of noteworthy trends here from a different perspective, i.e., in terms of the resources being invested in R&D in private industry. To facilitate this study, we conducted a questionnaire survey of 1,494 companies in the private sector (receiving replies from 742 companies) and held hearings to get the opinions of experts. The results are discussed below. (The questionnaire responses are summarized in an appendix at the end of this volume)

<1> **R&D Expenditure Increasing Sharply**

a) R&D expenditure in Japan is increasing rapidly, particularly in the manufacturing industries (Figure 2-2-2-2), and the ratio of this expenditure to sales is rising sharply (Figure 2-2-2-6). These trends are particularly pronounced in the processing and assembly industries. R&D expenditure in the electrical equipment industry has doubled in the last 5 years, reflecting the increased use of electronics technology (Figure 2-2-2-7).

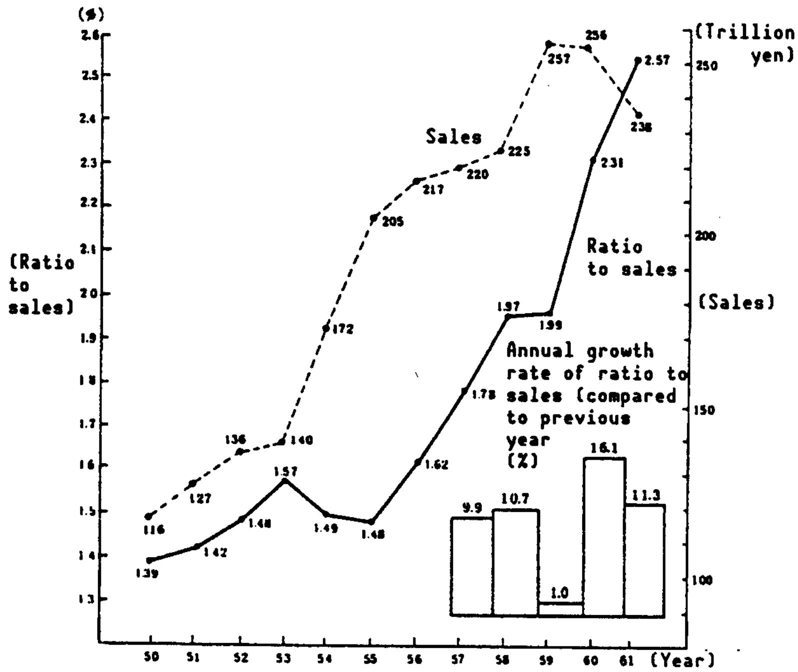


Figure 2-2-2-6 Trends in Ratio of Industrial Research Funding to Sales

Note: "Ratio to sales" is research expenditure divided by sales, excluding special corporations.
"Sales" refers to gross sales of companies conducting research.
Source: Prepared from "Scientific & Technological Research Survey Report."

Of particular interest is the fact that, in the manufacturing industries, the ratio of R&D expenditure to capital investment has been rising year after year (Figure 2-2-2-8). In some segments of the automobile and electrical equipment industries in FY 1986, R&D expenditure outstripped plant and equipment investment by a wide margin (Figure 2-2-2-9).

(b) These trends are thought to reflect the increasing necessity of companies to move toward diversification and basic research as they implement "survival strategies" in the face of numerous environmental difficulties. The latter include declining revenues due to the maturing of markets in general, the persistently strong yen, and heightened global competitive strategies in which science and technology feature prominently.

	R&D expenditure (x ¥100 million)			Full-time research staff		
	FY 1981	FY 1986	5-year growth	FY 1981	FY 1986	5-year growth
All industries	36,298	61,202	68.6	184,889	251,771	36.2
Agriculture, forestry, fisheries	48	43	-10.4	300	197	-34.3
Mining	129	217	68.2	637	698	9.6
Construction	729	1,211	66.1	4,829	5,752	19.1
Manufacturing	33,742	57,396	70.1	175,088	239,792	37.0
Basic materials	10,965	18,502	68.7	55,475	74,016	33.4
Steel	1,697	2,553	50.4	4,800	5,405	126
Chemicals	6,174	9,836	59.3	32,847	42,523	29.5
Other	3,094	6,113	97.6	17,828	26,088	46.3
Processing and assembly	20,025	35,481	77.2	99,006	146,574	48.0
General machine industry	2,421	3,791	566	15,390	21,313	385
Electrical equipment industry	10,062	19,800	96.8	58,873	89,824	52.6
Automobile industry	5,235	8,404	60.5	13,541	18,985	40.2
Other	2,307	3,486	51.1	11,202	16,452	46.9
Consumer-oriented industries	1,773	2,602	46.8	12,717	14,525	14.2
Textiles	645	627	-2.8	2,371	3,956	668
Other	1,128	1,975	75.1	10,346	10,569	22
Other industries	979	812	-17.1	7,890	4,677	-40.7
Transportation, communications, public works	1,650	2,335	41.5	4,035	5,332	32.1

Figure 2-2-2-7 Growth of R&D in Private Industry (FY 1981-1986)

Source: Prepared from "Science & Technology Research Survey Report" of General Affairs Agency

(2) Greater Emphasis on Basic Research

A) In recent years, the demarcation between science and technology has become increasingly vague as the so-called "S&T resonance" phenomenon has manifested itself. In this context, Japanese industry has become more and more involved in basic as well as applications research, particularly in such areas as ultraprecision machining, and controlling the structures and evaluating the performance of materials at the atomic and molecular levels. This trend is evidenced by the increasing investments in capital and human resources being made in basic research fields by private industry (Figures 2-2-2-11, 2-2-2-12).

B) In the background of these developments, it is believed, are the increasingly acute necessities for companies to come up with more creative technologies and to carry on basic research concurrently with applications/developmental research (Figure 2-2-2-13).

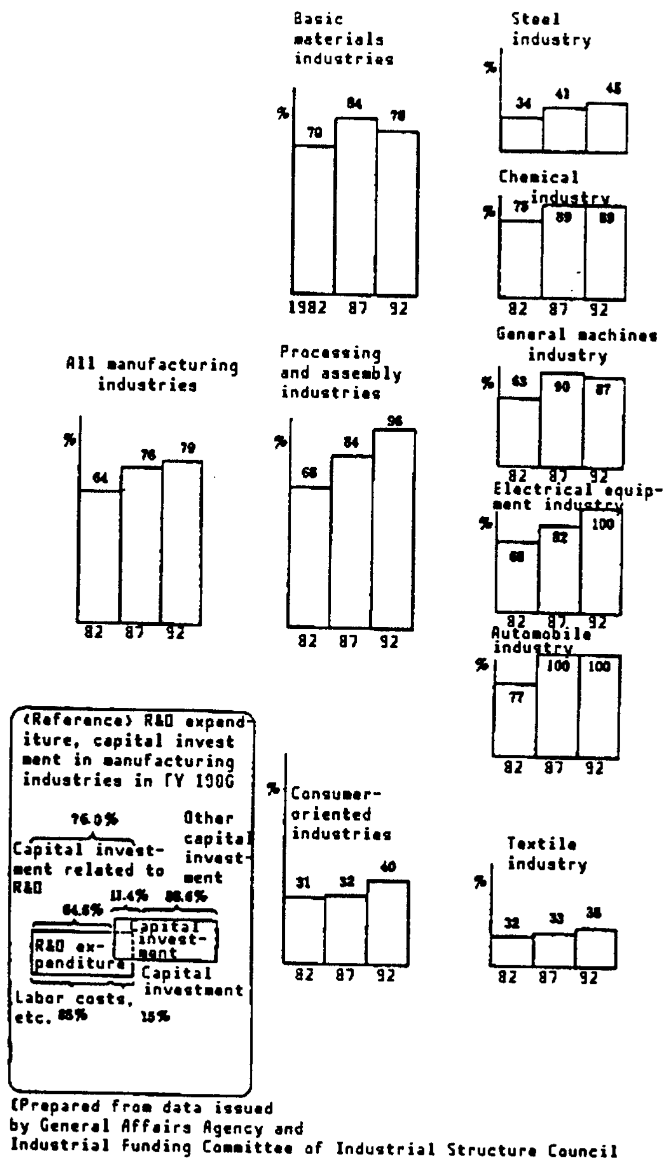


Figure 2-2-2-8 R&D Expenditure as a Percentage of Capital Investment

Source: "Questionnaire Survey of Research Activities" conducted by Agency of Industrial Science and Technology, February-April 1988 (issued May 1988). A total of 1,494 companies in the private sector were surveyed, 742 of which responded (49.7 percent). (Cf Appendix 4)

		R&D expenditure	R&D expenditure/sales (Indus mean: 2.6)	Capital investment	R&D expenditure Capital investment
1	Hitachi, Ltd.	2,515	8.6	1,008	2.50
2	Toyota Motor Co.	2,500	4.1	2,970	0.84
3	Nippon Electric	2,400	11.3	1,600	1.50
4	NTT	1,775	3.3	16,132	0.11
5	Toshiba Corp.	1,716	6.9	1,195	1.44
6	Fujitsu, Ltd.	1,580	10.7	846	1.87
7	Nissan Motor Co.	1,550	4.5	950	1.63
8	Mitsubishi Electric	1,120	6.2	620	1.81
9	Mitsubishi Heavy	870	5.3	707	1.23
10	Mazda Motor Corp.	800	4.9	1,100	0.73

Note: 10 top R&D companies according to KAISHA SHIKIHO [JAPAN COMPANY HANDBOOK]
Source: KAISHA SHIKIHO (1988)

Figure 2-2-2-9 R&D Expenditure, Capital Investment in Major R&D Industries (FY 1986)

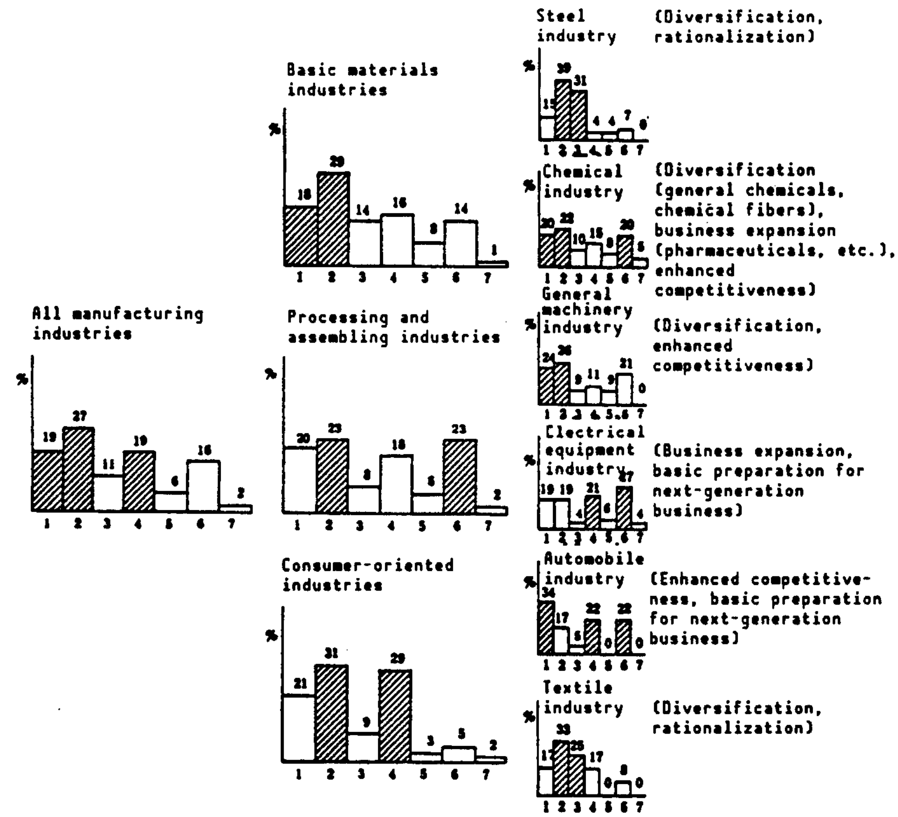
Answers

1. This industry is growing and competition (cost, quality) with other companies is severe.
2. The market is maturing and revenues are declining in this industry, making it necessary to diversify for business reasons.
3. Economic environment is changing dramatically due to trade friction, strong yen, etc., and doubts are deepening concerning the future underpinnings of the industry, so rationalization and diversification are called for.
4. Have decided to make preparations for moving into new business areas while revenues from current business are stable and high.
5. Business to date has been based heavily on acquired technology; difficulties with further acquisition make it necessary to develop own technology.
6. Nature of business places high priority on R&D, and the scale of business operations is expanding.
7. Other.

Figure 2-2-2-10 Reasons for Increased R&D Expenditure

[figure continued]

[Continuation of Figure 2-2-2-10]



Source: "Questionnaire Survey of Research Activities," Agency of Industrial Science and Technology (May 1988)

	FY 1980	FY 1985	FY 1986	FY 1986/80
Total research expenditure (x ¥10 billion)	314	594	612	1.9
Basic research expenditure (x ¥10 billion)	16	35	37	2.4
Basic/total research expenditure (percent)	5.0	5.9	6.1	--

Source: Prepared from "Science & Technology Research Survey Report" of General Affairs Agency.

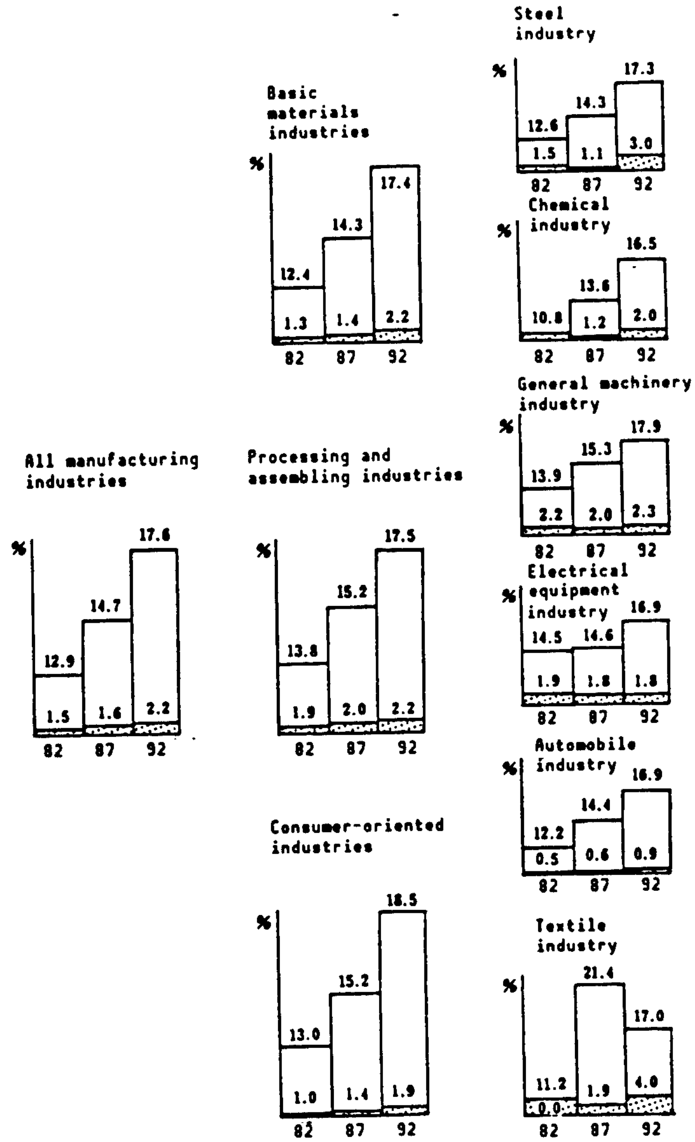


Figure 2-2-2-12 Trends in Percentage of Researchers in Basic Research

Note: Shaded portion of graph indicates pure basic research.

Source: "Questionnaire Survey of Research Activities," Agency of Industrial Science and Technology (May 1988)

Answers

1. It becomes necessary, in conducting applications/developmental research, to delve back into basic areas.
2. In order to begin with basic research, move on to applications and development, and thereby create revolutionary technology.
3. It becomes difficult to acquire technology in advanced fields without doing basic research.
4. Knowledge provided by basic research is necessary for survival in technological fields.
5. Indispensable in grasping future technological developments.
6. Other.

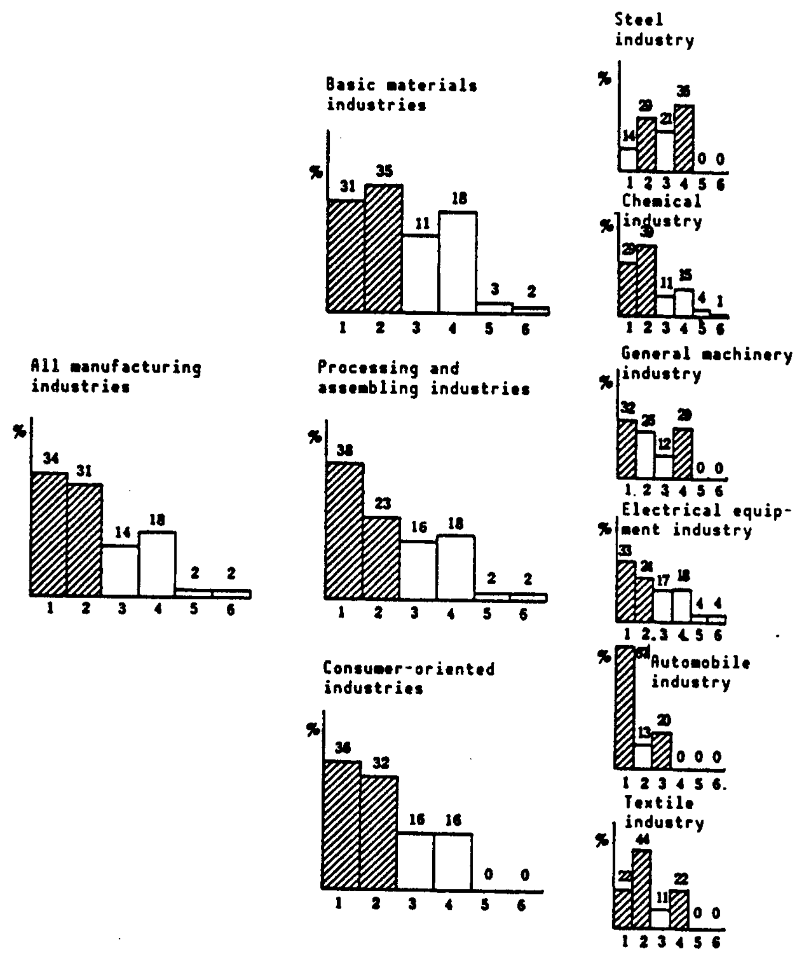


Figure 2-2-2-13 Reasons for Giving More Priority to Basic Research

Source: "Questionnaire Survey of Research Activities," Agency of Industrial Science and Technology (May 1988)

Answers

1. Basic research should be left to universities and national testing laboratories while industry concentrates on applications and development.
2. Industry should also be engaged in basic research through joint projects done with universities and national testing laboratories.
3. In addition to joint research (answer 2 above), industry should also conduct basic research on its own.
4. Other.

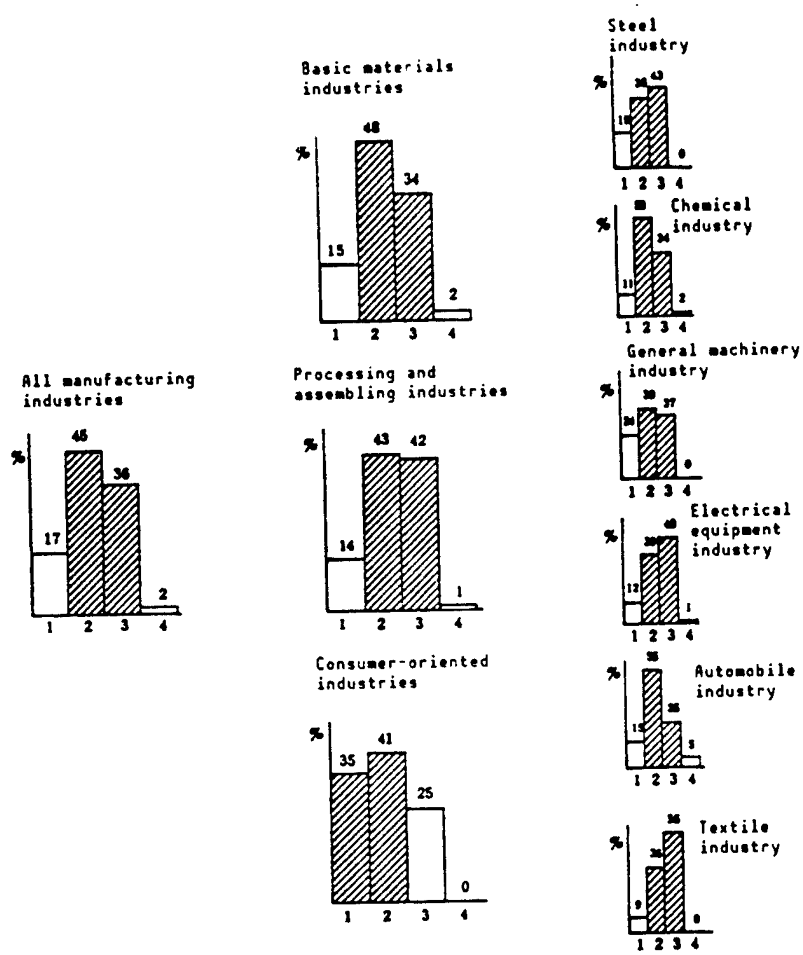


Figure 2-2-2-14 Who Should Be Responsible for Doing Basic Research

Source: "Questionnaire Survey of Research Activities," Agency of Industrial Science & Technology (May 1988).

C) Most basic research being done in industry, however, is being done in fields which are relatively close to applications research (so-called goal-oriented basic research), and the percentage of overall basic research which is being done in basic science (pure basic research) is no more than 10 percent or so. Hence the basic research being done by Japanese industry is believed to be of limited depth.

D) As to the question of who is primarily responsible for pursuing basic research, opinion in private industry is divided. According to one view, basic research should be the province of the universities and the national testing laboratories, while industry gives itself entirely to applications and developmental research. This opinion is held by less than 2 out or 10 industrial leaders, however, while better than 8 out of 10 hold that industry should also be involved in basic research, either on its own or in joint universities and national laboratories. Nearly 4 out or 10 believe that industry should conduct basic research on its own, a fact which is indicative of the importance attached to basic research in the private sector. In seeking more effective basic research, private industry also looks with expectation to the universities and national laboratories as potential partners in joint research (Figure 2-2-2-14).

(3) Acquisition of Research Personnel

A) Against the background of intensified R&D and diversification, the number of researchers is increasing in almost all industries, with the exception of agriculture, forestry, and fisheries. In some fields researcher shortages have developed.

B) This trend is expected to become increasingly pronounced, judging by the intensity of industry efforts to acquire research personnel (the growth in the number of full-time research personnel over the next 5 years is projected to be at a higher rate than during the past 5 years, generally speaking (Figure 2-2-2-15)). For most industries, the shortage of research personnel is a greater problem in carrying on R&D than is the shortage of either research facilities or capital (Figure 2-2-2-16).

C) As R&D activity is increasingly marked by diversification and technological cross-fertilization, it is becoming more necessary to retain researchers for work in other fields (than that primarily engaged in by the hiring company). This trend is particularly pronounced in advanced technological fields. As a result, the demand for research personnel working in interdisciplinary fields is rising faster than it can be met. (Roughly 7 out of 10 companies report that they do not know where they will get the human resources which they will need 5 years from now) (Figure 2-2-2-17, 2-2-2-18).

D) For this reason, private industry ardently hopes that the universities will turn out highly creative researchers, and encourages the development of research personnel who can cope with the changes both in science and technology and in industrial needs. According to the results of a questionnaire survey, more than 7 out of 10 companies are critical of the universities for failing to produce more creative researchers, and more than 4 out of 10 criticize the universities for failing to produce researchers with the qualifications needed by industry (Figure 2-2-2-19).

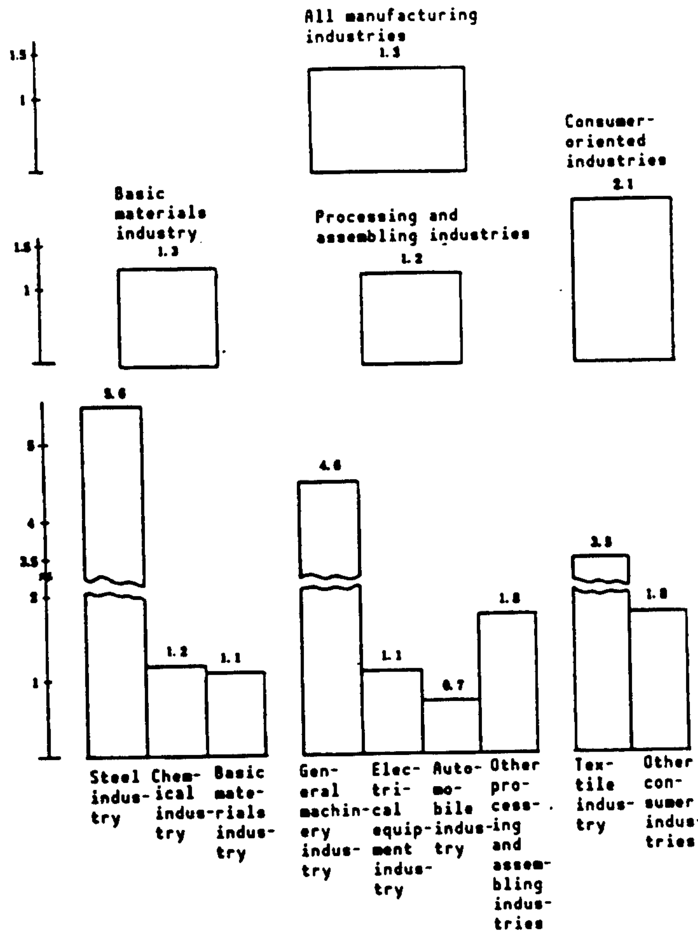


Figure 2-2-2-15 Trends in Full-Time Research Personnel

(Factor by which 1992/87 growth rate (projected) will exceed 1987/82 rate)

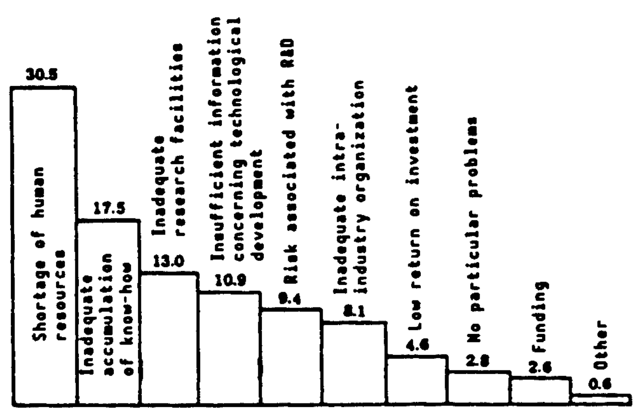


Figure 2-2-2-16 Problems in Conducting Research and Development

Source: Prepared from data issued by General Affairs Agency and Industrial Funding Committee of Industrial Structure Council (April 1988)

(Units = number of persons, %)

Field of specialization	Biotechnology		Computer science		New materials		Robotics		New energy	
	Research personnel	Percentage	Research personnel	Percentage	Research personnel	Percentage	Research personnel	Percentage	Research personnel	Percentage
Mathematics, physics	38	1.6	732	15.7	565	12.1	209	13.9	78	11.0
Chemistry	543	23.0	131	2.8	2,411	51.8	16	1.1	182	25.8
Mechanics	50	2.1	537	11.5	369	7.9	743	49.6	167	23.7
Electricity	30	1.3	2,572	55.2	361	7.8	432	28.8	81	11.5
Metals, natural resources	4	0.2	25	0.5	577	12.4	17	1.1	44	6.2
Civil engineering, architecture	21	0.9	52	1.1	69	1.5	16	1.1	95	13.5
Biology	1,086	46.1	83	1.8	23	0.5	1	0.1	32	4.5
Medicine, pharmacology	432	18.3	27	0.6	14	0.3	6	0.4	1	0.1
Other natural sciences	148	6.3	116	2.5	189	4.1	12	0.8	20	2.8
Liberal arts, social sciences	5	0.2	386	8.3	79	1.7	47	3.1	6	0.8
Total	2,357	100.0	4,661	100.0	4,657	100.0	1,499	100.0	706	100.0

Figure 2-2-2-17 Utilization of Research Personnel in Advanced Technology (combined totals for industry and national, public research facilities)

Note: The top three fields of specialization are circled.
Source: "Wagakuni in okeru kenkyu jinzai no genjo to jukyu doko in kansuru kiso chosa [Basic Survey of Research Personnel in Japan--Current Status and Supply-Demand Trends]," Science and Technology Agency (March 1987).

E) Many companies in the private sector are implementing innovative measures in the research management area in the interest of acquiring needed research personnel. These measures include giving greater priority to research themes and making research activities more efficient. Many companies also cite the pressing need for closer cooperation with universities and national testing laboratories. In addressing the problem of the current shortage of research personnel, industry looks expectantly to the universities and national laboratories, hoping to utilize their stock of human resources and to see greater coordination between industry, academia, and government agencies (Figure 2-2-2-20).

(4) R&D Diversification

A) Although further specialization is occurring in a few industries, such as the electrical equipment and automobile industries, diversification into different or entirely new fields is being pursued in most industries (notably the textile, steel, and general machinery industries) as revenues decline due to the maturing of traditional markets (Figure 2-2-2-10, 2-2-2-21, 2-2-2-22).

B) According to the Industrial Funding Committee of the Industrial Structure Council, a third of all manufacturing industries have now moved into new areas of business. Some 60 percent are expected to be moving into new business, including those now making plans for doing so (Figure 2-2-2-23).

Answers

Percentage of needed researchers thought possible to acquire:

1: Nearly 100 percent	5: 40~50 percent
2: 80~90 percent	6: 20~30 percent
3: 70~80 percent	7: Approximately 10 percent
4: 50~60 percent	8: 9 percent or less

[The Japanese units in the original table are much less precise than the percent unit; hence the seeming inconsistency]

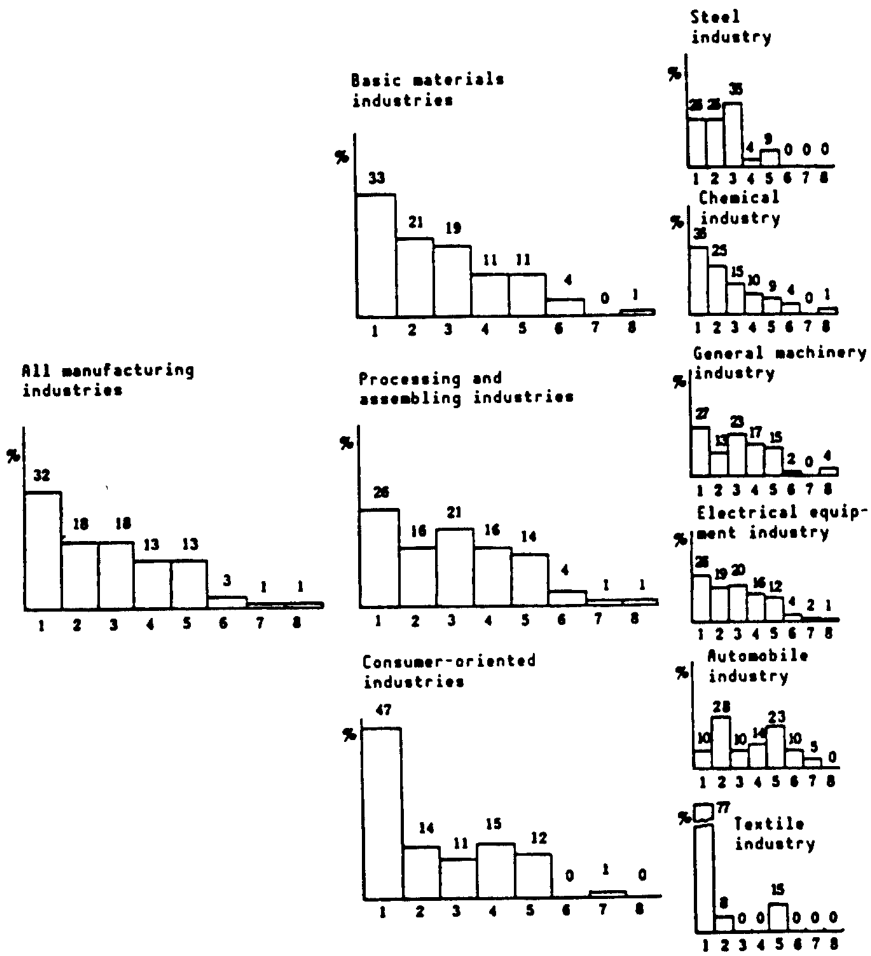


Figure 2-2-2-18 Projected Researcher Acquisition (projected acquisition of full-time researchers in FY 1992)

Source: "Questionnaire Survey of Research Activities," Agency of Industrial Science & Technology (May 1988).

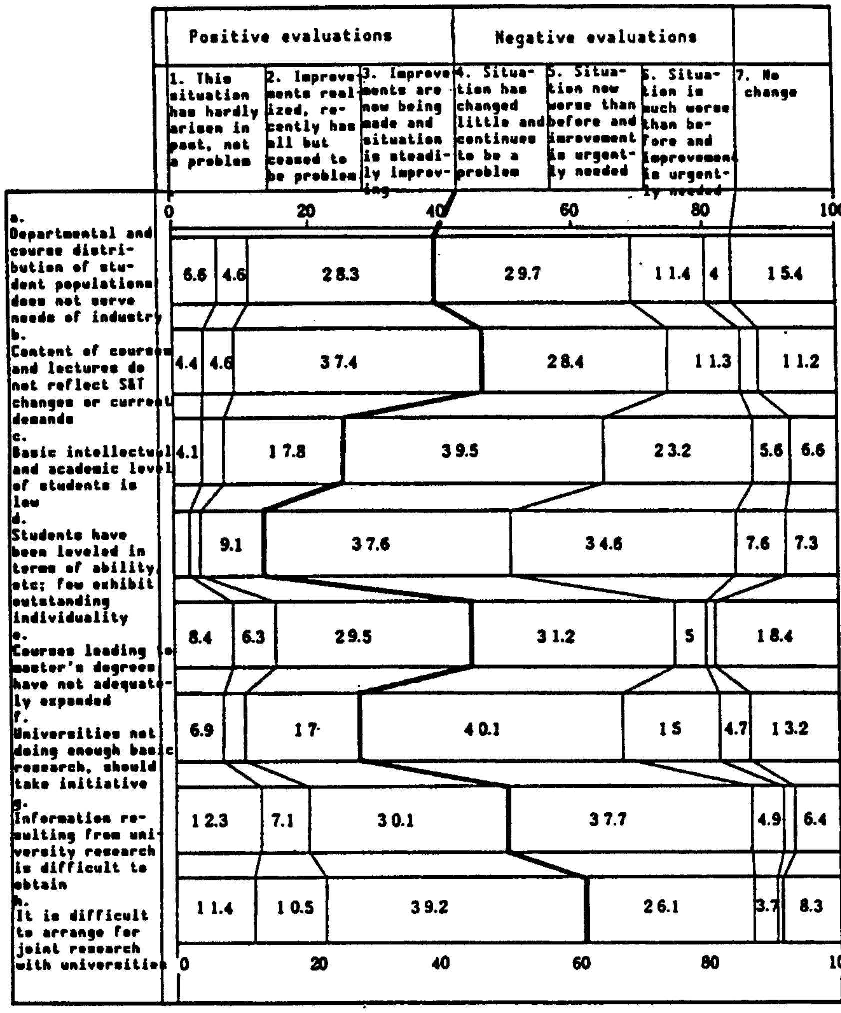


Figure 2-2-2-19 Industry Expectations Concerning Universities

Source: "Questionnaire Survey of Research Activities," Agency of Industrial Science & Technology (May 1988).

Answers

1. Raise efficiency of R&D activity by more sophisticated research management.
2. Screen research areas and themes more severely by using more difficult research theme priority evaluations.
3. Take some of the load off of full-time researchers by upgrading the capabilities of research assistants.
4. Promote the policy of undertaking some research activities in areas within the company.
5. Promote closer ties with other private companies for cooperative research activities.
6. Promote closer ties with universities and national testing laboratories.
7. Utilize research supporters (private or public).
8. Other

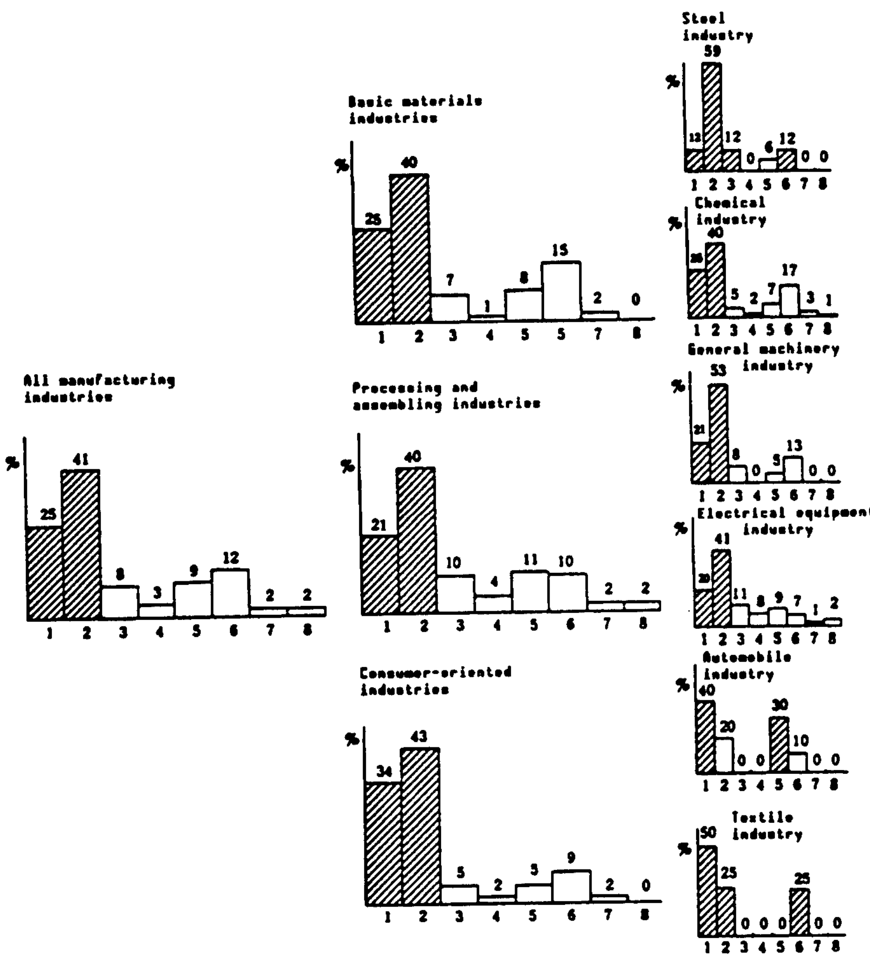


Figure 2-2-2-20 Research Personnel Measures

Source: "Questionnaire Survey of Research Activities," Agency of Industrial Science & Technology (May 1988).

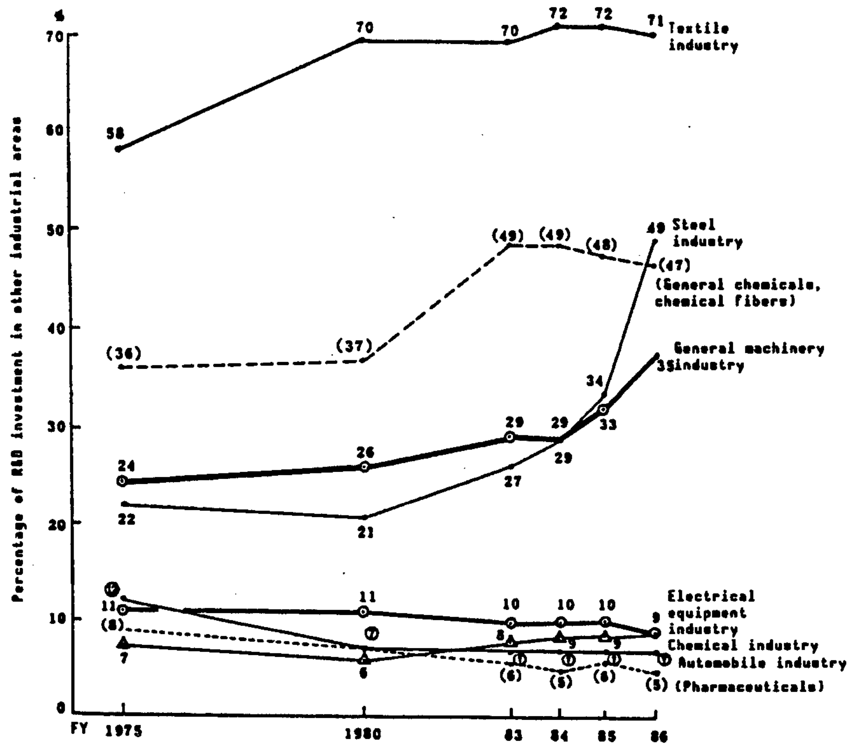


Figure 2-2-2-21 R&D Diversification (R&D investment in product fields in other areas)

Source: Prepared from "Scientific and Technological Research Survey Report," General Affairs Agency

C) Many of these new business fields are related to the company's existing business or involve related technology. However, many companies are also employing such new technologies as materials technology, electronics, and mechatronics as they move into new business areas (Figure 2-2-2-24).

D) The smaller companies are coping with the changing economic environment and the maturation of their traditional markets in two different ways.

a. Some are moving into new fields where they can use their proprietary technology and sales routes to good advantage.
b. Some small companies are forging ties with other small companies in different fields, merging their respective technologies and other corporate assets to develop new products and new services. This "melding" approach is being quite aggressively pursued in pioneering new business fields.

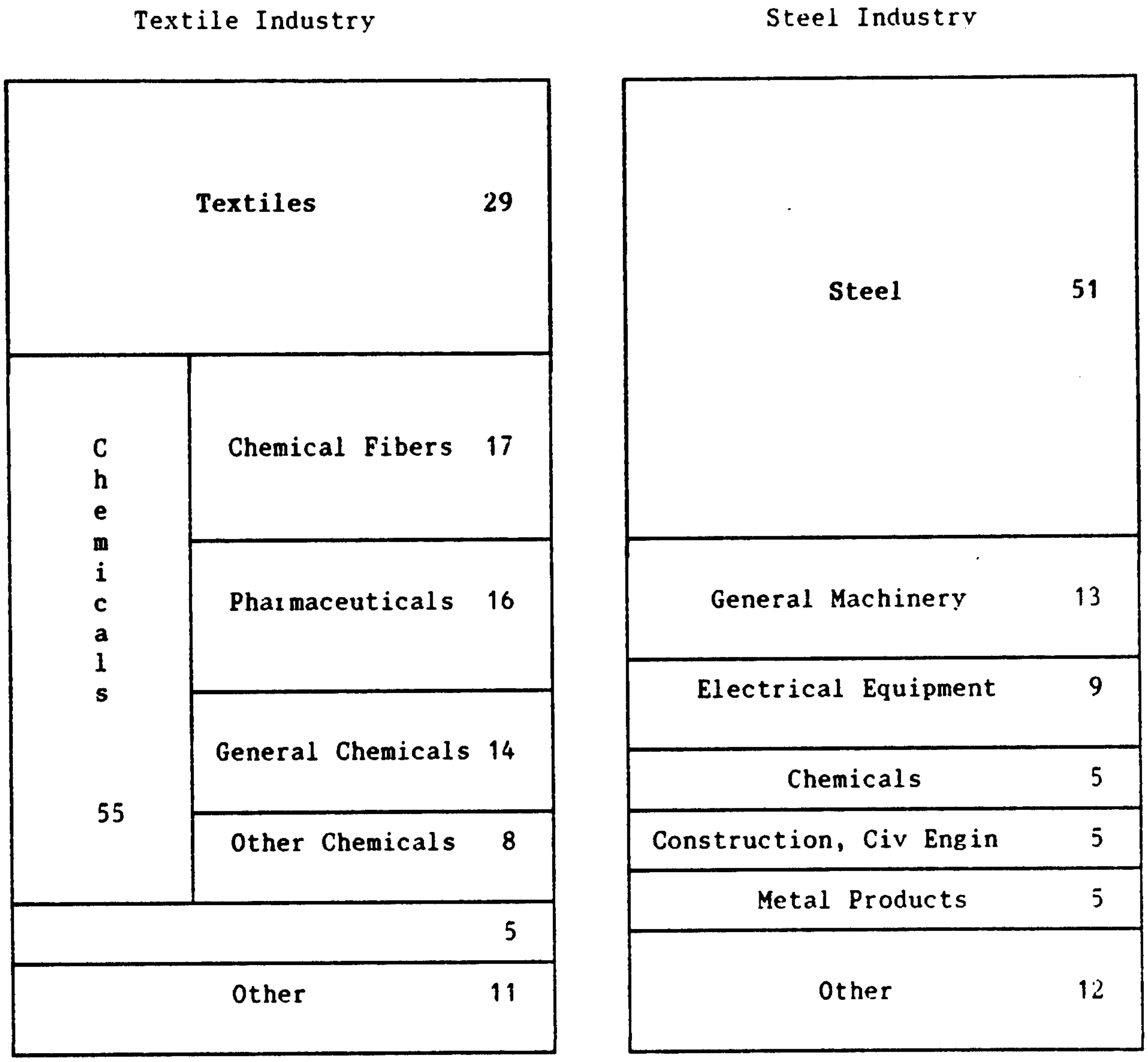


Figure 2-2-2-22 R&D Diversification in Textile, Steel Industries (R&D expenditure in industrial field, FY 1986 (percent))

Source: Prepared from "Scientific and Technological Research Survey Report," General Affairs Agency

E) These business developments are being supported by certain trends in industrial technology, including increased coordination and cross-fertilization between various industrial technologies. When we analyze the evolution of this technological cooperation and cross-fertilization by examining the academic field classification codes which are placed on technical papers, we find that these phenomena have been occurring at a very rapid tempo in Japan, outstripping even the United States since 1982 (Figure 2-2-2-25).

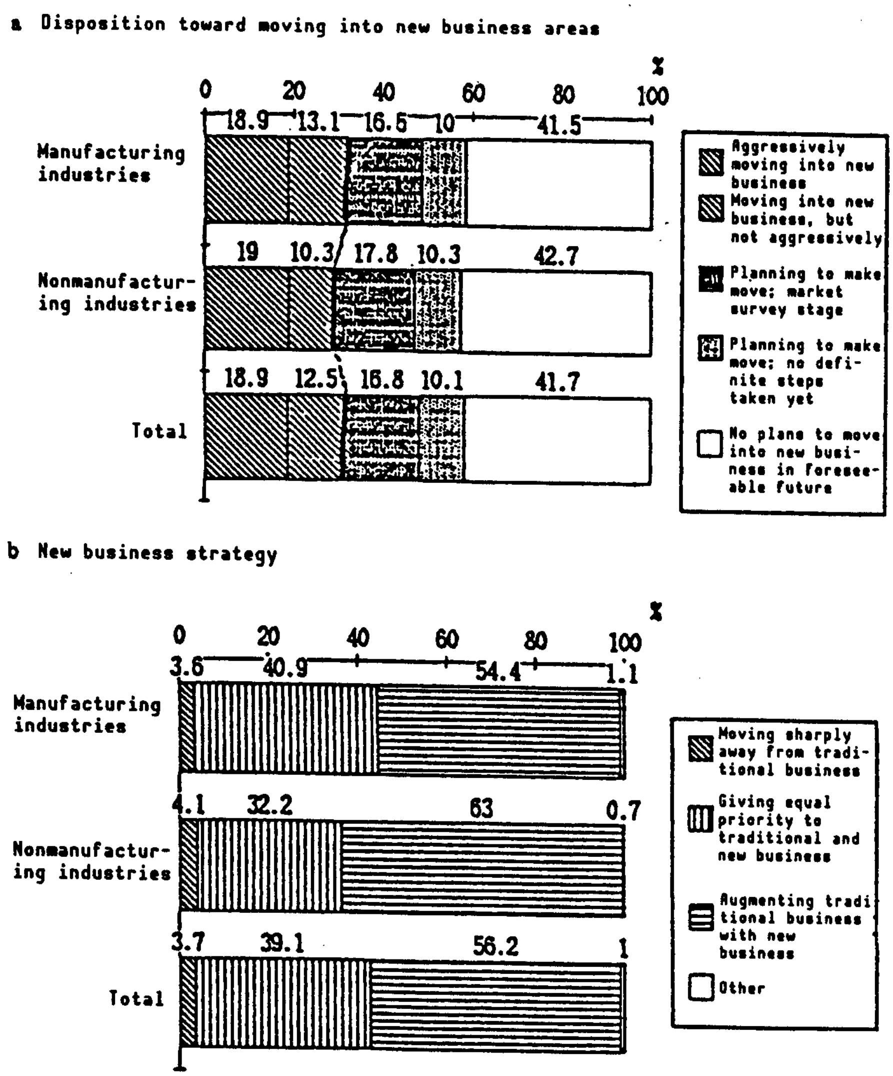


Figure 2-2-2-23 Undertaking New Business

Source: Industrial Funding Committee of Industrial Structure Council (April 1988)

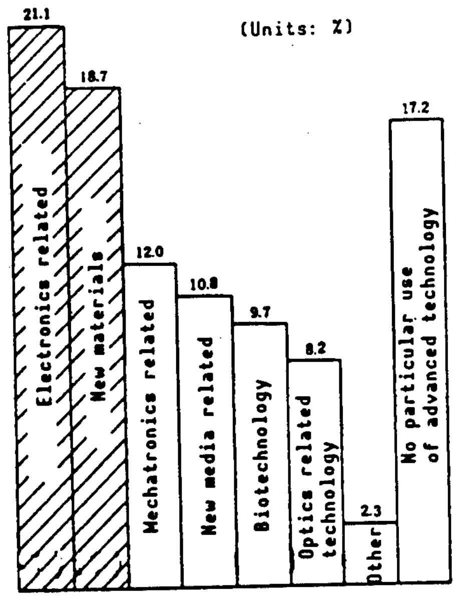


Figure 2-2-2-24 Utilization of Advanced Technology in Undertaking New Business

Source: Prepared from data made available by Industrial Funding Committee of Industrial Structure Council (April 1988)

[Notes to Figure 2-2-2-25]

1. The "technology coordination and cross-fertilization index (TC&CFI)" is a measure of the degree to which one technology is being coordinated and cross-fertilized with other technologies,* as calculated from the frequency with which a classification code occurs simultaneously with other classification codes in the literature.

   In the case of "A-1 Electromagnetic Signal Technology," for example, the calculation would be based on the following formula:

$$\text{TC\&CFI in "A-1" field} = \frac{\text{Number of bibliographic items in which "A-1" classification code occurs together with another classification code (total number of such items)}}{\text{Number of bibliographic items in which "A-1" classification code occurs}}$$

2. Based on retrieval operations using Compendex S&T bibliography database.

3. The following 24 technologies were studied:
   A. Electronics-General
      A-1 Electromagnetic wave technology
      A-2 Electronics and thermal materials
      A-3 Electronic circuitry

[notes to figure continued]

[Continuation of Figure 2-2-2-25]

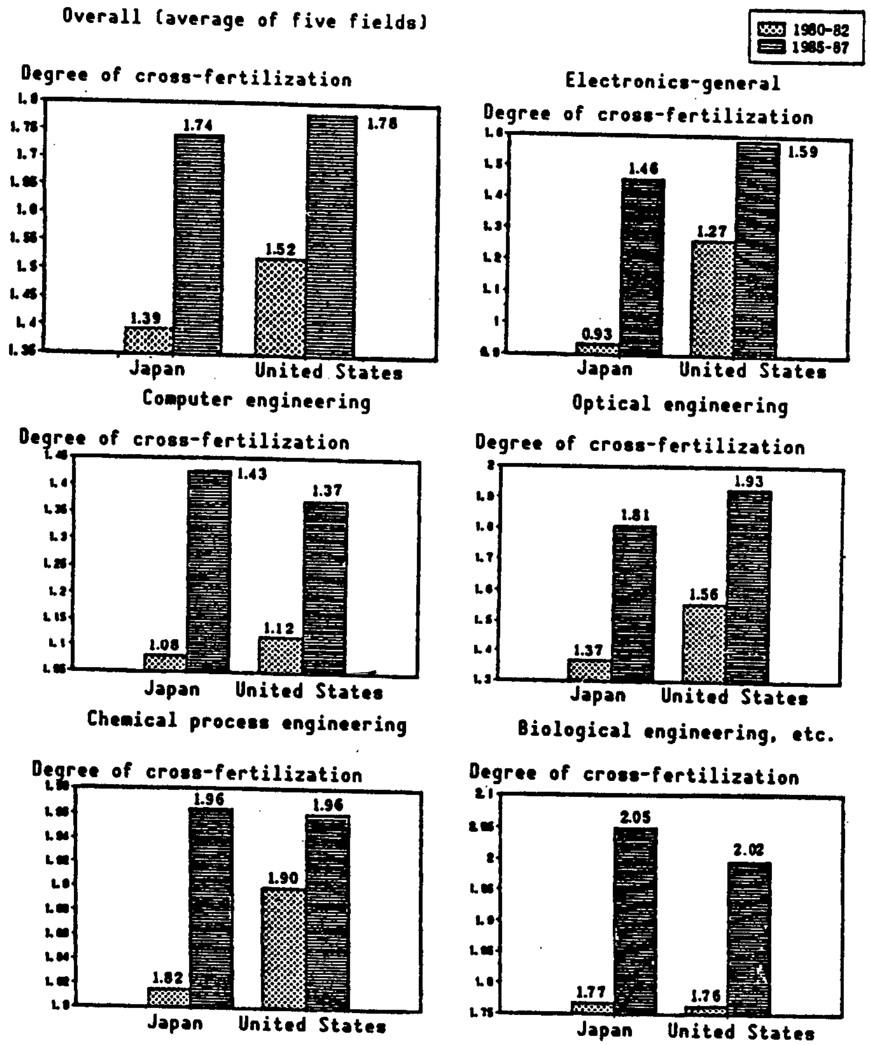


Figure 2-2-2-25 Evaluation of Technological Coordination and Cross-Fertilization by Bibliographic Database Retrieval

- A-4 Electronic components
- A-5 General electronic equipment
- A-6 Radio and television equipment
- A-7 Electronic and optical communication
- A-8 Telephone and cable communications

B. Computer Engineering
- B-1 Computer logic circuits
- B-2 Computer hardware
- B-3 Computer software

C. Optical Engineering
- C-1 Optical technology and equipment
- C-2 Photographic technology

[figure continued]

[Continuation of notes to Figure 2-2-2-25]

C-3 Holography
C-4 Laser engineering
C-5 Printer/copier technology

D. Chemical Process Engineering
D-1 Cellulose and wood products
D-2 Ceramics/refractory materials
D-3 Fiber technology
D-4 Polymer materials, etc.

E. Biological engineering, etc.
E-1 Biotechnology
E-2 Medical engineering/equipment
E-3 Agricultural equipment/technology
E-4 Food engineering

*"Other technologies" include a total of 37 technologies, including the advanced technologies noted in "3." above, as well as electrical engineering, mechanical engineering, and metallurgy.

Source: Prepared from a March 1988 survey conducted by the Agency of Industrial Science and Technology

(5) International Technological Exchange Intensifies

A) Commercial markets have become increasingly international in character, and Japanese industrial business activity has expanded internationally. Technological development has become necessary in connection with the development of overseas markets. In a growing number of areas of R&D activity, moreover, it is necessary for industrial entities of different countries to complement each other's technological know-how. As a result of these developments and trends, the tempo of international joint research and technological tie-ups has risen.

Cases are also seen in which joint research is promoted by inviting foreign researchers to work in Japan (Figure 2-2-2-26).

B) Technological exchanges between Japan and foreign entities will continue to be actively conducted, regardless of the type of industry, and the technological tie-up (involving import/export licenses) has become the dominant mode of technological exchange (Figure 2-2-2-27). International technological exchange is expected to intensify, not only in the form of exchanging technological information between researchers and institutions, but also in the form of implementing joint research with advanced nations. In implementing such joint R&D in advanced technological fields, moreover, we may expect to see wider exchange between Japanese companies and foreign companies in different industries.

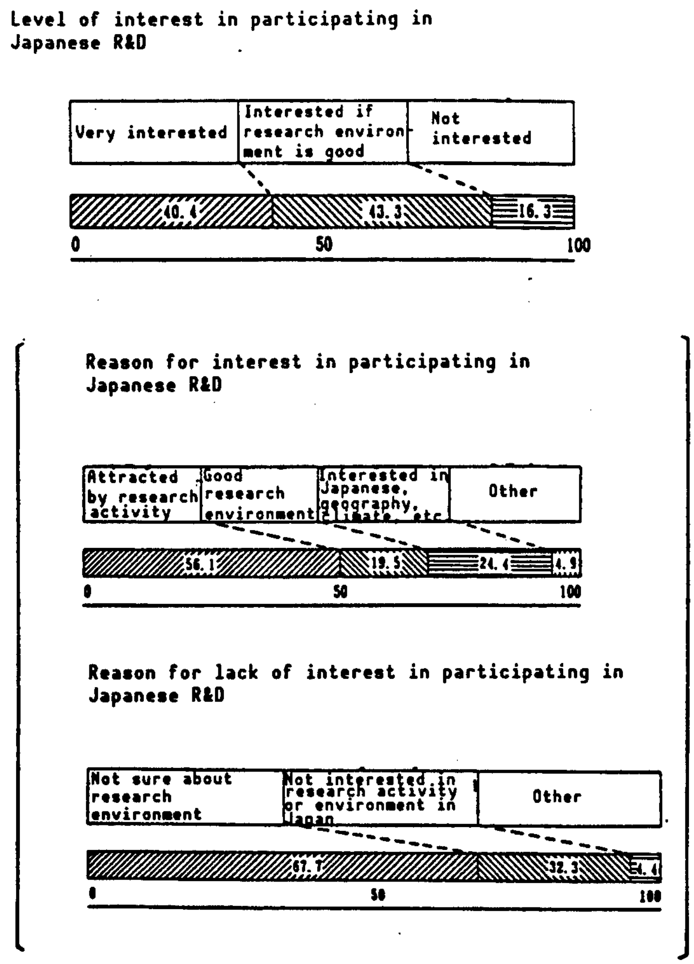


Figure 2-2-2-26 Attitudes of Foreign Researchers Toward Japanese R&D Activity

Note: Based on results of a questionnaire survey of 161 researchers at universities, national research facilities, and private industry research facilities in the United States, West Germany, and the United Kingdom.

Source: Tsukuba Kagaku Banpaku Kinen Dantai [Tsukuba Science Fair Commemoration Foundation]

C) As Japanese industries--most notably the automobile and electrical equipment industries--increasingly move into U.S. and other foreign markets, more and more research facilities are being built overseas to support applications R&D for the purpose of developing products that coincide with local market demand. This activity is part of the market development strategy that also includes information gathering (Figure 2-2-2-28, 2-2-2-29). In another trend that has begun to manifest itself recently, basic research laboratories are being established overseas, so that foreign research resources can be tapped for creative R&D efforts, and so that more conducive research environments can be taken advantage of.

Answers

1. Information exchange between researchers of research organizations, done through academic and scientific societies
2. Commissioned research
3. Joint research
4. Technological tie-ups (export/import licensing)
5. Other

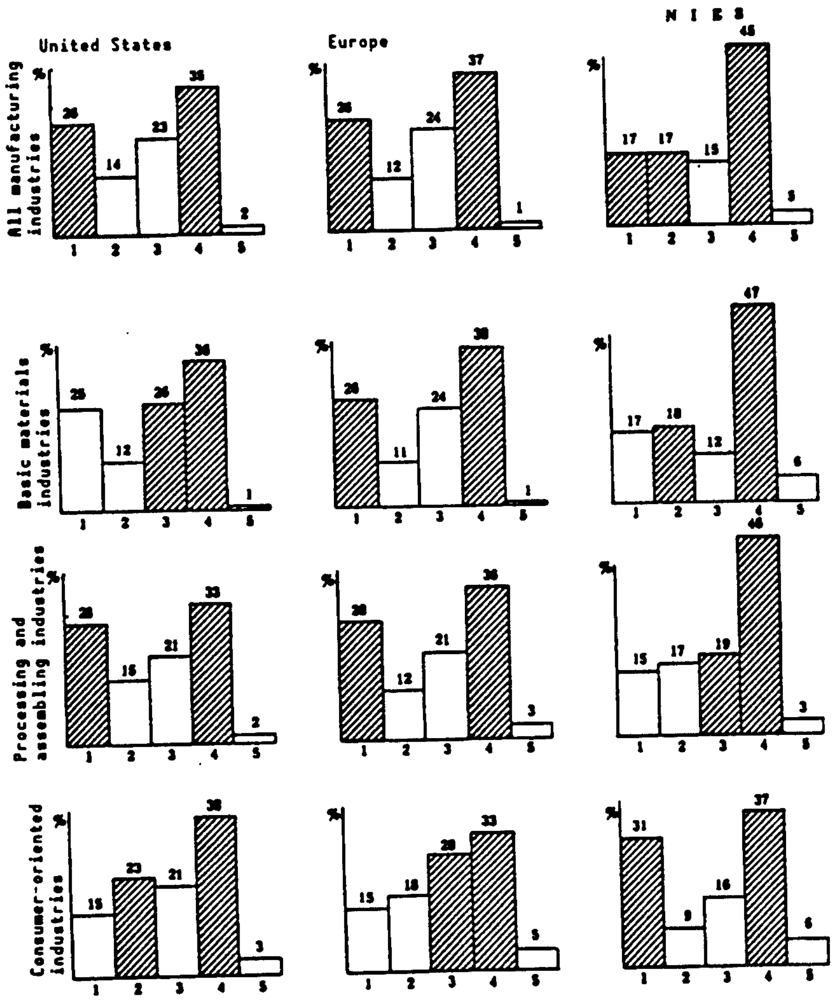


Figure 2-2-2-27 Future Modes of R&D Exchange With Foreign Entities

Source: "Questionnaire Survey on Research Activity," Agency of Industrial Science and Technology (May 1988)

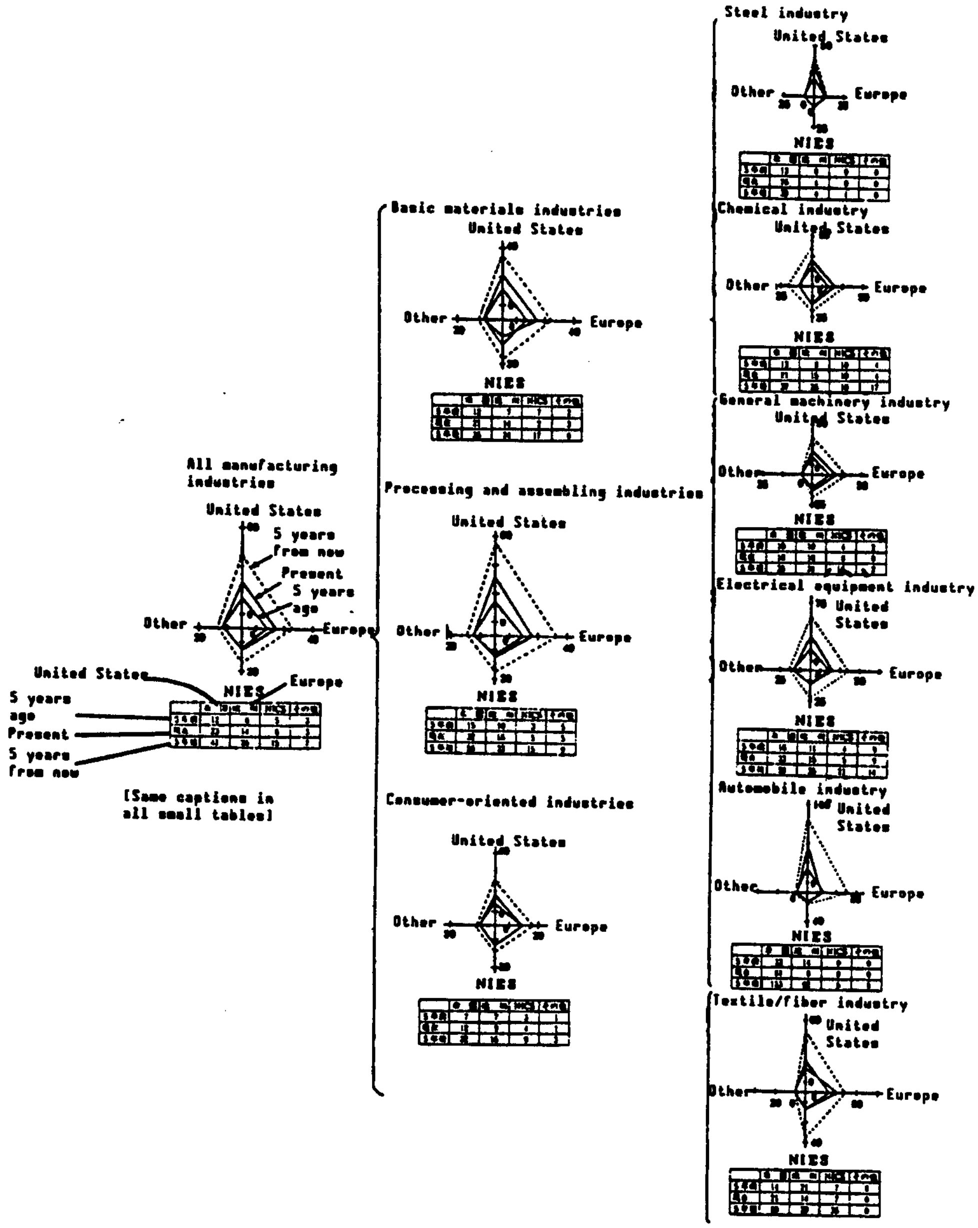


Figure 2-2-2-28 Overseas R&D Centers (Number of centers per 100 companies)

Source: "Questionnaire Survey of Research Activities," Agency of Industrial Science & Technology (May 1988).

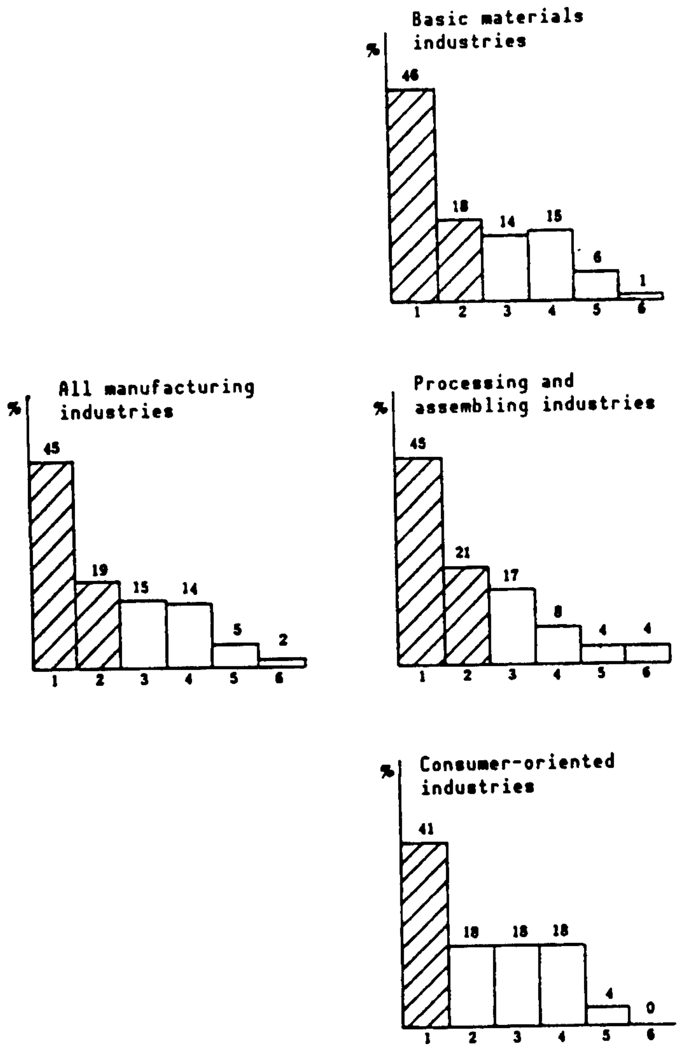


Figure 2-2-2-29 Function of Overseas R&D Centers

Source: "Questionnaire Survey of Research Activities," Agency of Industrial Science & Technology (May 1988).

(6) Location of Research Facilities

A) One recent and pronounced trend in private industry is the rapid rate at which industrial research facilities are being established for research and development. In the early 1960's there was a boom in creating such facilities. This more recent one is being called the "second research facility boom."

In terms of the number of building projects, the recent boom far outstrips the first one. The first boom was motivated by the need to catch up in technology, to establish one's own technology, and to coordinate R&D functions in coping with the changing objectives of technological development.

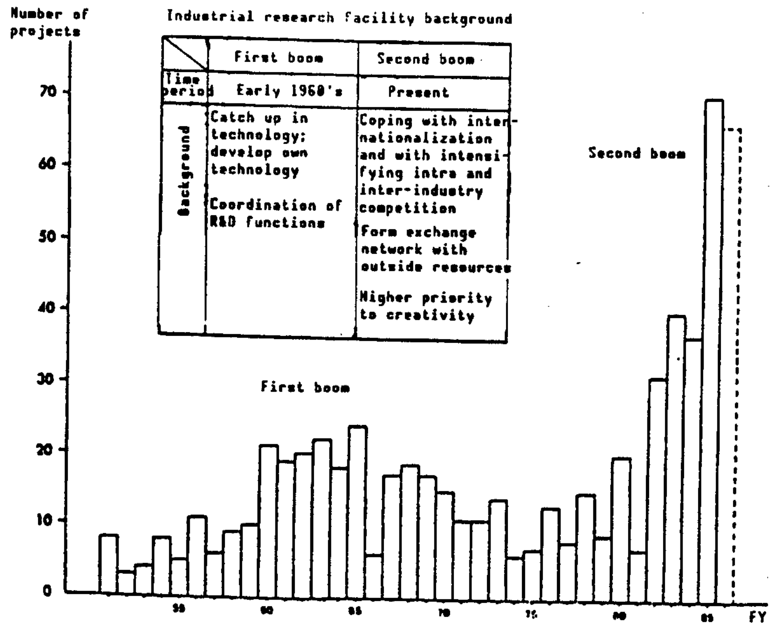


Figure 2-2-2-30 Trends in Industrial Research Facilities
Source: Survey conducted by Agency of Industrial Science and Technology (March 1987)

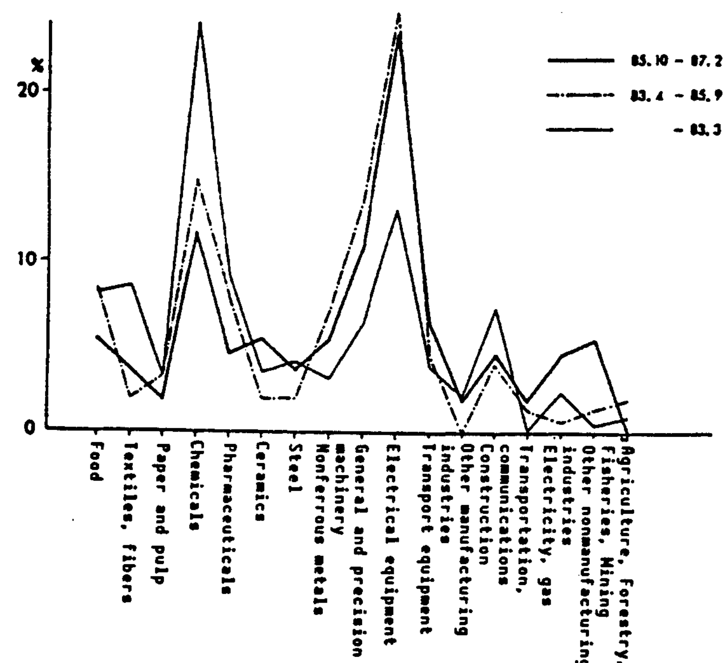


Figure 2-2-2-31 Research Facility Establishment by Industry
Source: Survey conducted by Agency of Industrial Science and Technology (March 1987)

Behind the second boom is a greater emphasis on basic research in which creativity is given high priority, on the need to cope with internationalization, and on the intensification of competition, both within the same industry and between different industries (Figure 2-2-2-30).

B) Looking at particular industries, the chemical industry led in the establishment of new research facilities until 1982. In more recent years, many research facilities have been built by companies belonging to the electrical equipment, machinery (general and precision), ceramics, and chemical industries. Most of these facilities are geared to high-tech research in new materials, electronics, mechatronics, and biotechnology (Figure 2-2-2-5, 2-2-2-31, 2-2-2-32).

Upjohn Pharmaceuticals, Ltd.: Tsukuba General Research Facility
Tsukuba, Ibaraki Prefecture Completion: (1988)
Cost: ¥14 billion Site: 75,000 m^2 Floorspace: 22,300 m^2

Eastman Kodak (U.S.): Research & Development Center
Yokohama, Kanagawa Prefecture Completion: (September 1988)
Cost: ¥10 billion

NMB Semiconductor: Research Facility
Tateyama, Chiba Prefecture Completion: (Early 1986)
*1986 total investment ¥10 billion

Osaka Gas Co.: New Research Facility
Kansai Kakken Toshi Construction start: (1990)
Cost: ¥5~6 billion Floorspace: 25,000 m^2

Oki Electric Industry Co., Ltd.: System Development Center
Warabi, Saitama Prefecture Completion: October 1986
Cost: ¥5 billion Floorspace: 25,000 m^2

Ono Pharmaceutical Co., Ltd.: Fukui Safety Research Facility
Fukui Prefecture Completion: April 1985
Cost: ¥5 billion Site: 161,000 m^2

: New Building, Central Research Facility
Shimamoto-cho, Osaka Prefecture Completion: (Spring 1987)
Cost ¥5 billion New building floorspace: 6,000 m^2

Olympus Optical Co., Ltd.: Technology Research Facility
Hachioji, Tokyo Prefecture Completion: (November 1987)
Cost: ¥10 billion Site: 40,000 m^2

Figure 2-2-2-32 Recently Announced Research Facilities Costing ¥5 Billion or More (Examples in AIUEO order) (Note: KENKYUJO is variously rendered "research laboratory," "research institute," etc. In this figure it is rendered consistently "research facility."] [figure continued]

[Continuation of Figure 2-2-2-32]

Canon Inc.: Central Research Facility		
Atsugi, Kanagawa Prefecture	Completion:	March 1985
Cost: ¥10 billion	Floorspace:	13,000 m^2
Kumagai Gumi Co., Ltd.: Tsukuba Technological Research Facility		
Tsukuba, Ibaraki Prefecture	Completion:	(January 1988)
Cost: ¥8 billion	Floorspace:	16,500 m^2
KDD: No 2 Research Facility		
Kami-Fukuoka, Saitama Prefecture	Construction start:	Early 1986
Cost: ¥6 billion	Floorspace:	9,000 m^2
Kobe Steel, Ltd.: New Research Facility, Phase 1		
Kishi-ku, Kobe, Hyogo Prefecture	Completion:	(May 197)
Cost: ¥10 billion (inclusive of land price)		
Kobayashi Kose: Research Facility Renovation		
Kita-ku, Tokyo	Completion:	(1988)
Cost: ¥5 billion	Floorspace:	9,900 m^2
Komatsu, Ltd.: New Research Facility		
Hiratsuka, Kanagawa Prefecture	Completion:	April 1985
Cost: ¥15 billion	Floorspace:	23,300 m^2
Sankyo: Research Building		
Shinagawa, Tokyo	Completion:	May 1986
Cost: ¥12 billion		
: New Research Facility		
Tsukuba, Ibaraki Prefecture	Construction start:	Spring 1989
Suntory, Ltd.: Medical Research Center		
Chiyoda-machi, Gunma Prefecture	Construction start:	December 1986
Cost: ¥13 billion	Site:	100,000 m^2
: General Research Center		
Senri District, Osaka	Construction start:	1986
Cost: ¥30 billion		
Sanyo Electric Co., Ltd.: Tsukuba Research Facility		
Tsukuba, Ibaraki Prefecture	Completion:	October 1985
Cost: ¥6 billion	Floorspace:	10,000 m^2
Sanraku Inc.: Safety Research Facility		
Fujisawa, Kanagawa Prefecture	Established:	April 1985
Cost: ¥5 billion		

[figure continued]

[Continuation of Figure 2-2-2-32]

Sumitomo Chemical Co., Ltd.: General Research Center
Tsukuba — Completion: (Spring 1988)
Cost: ¥15 billion

: Safety Research Building
Osaka — Completion: (Late 1987)
Cost: ¥8 billion — Floorspace: 20,000 m^2

Sumitomo Electric Industries, Ltd.: Basic Technology Research Facility
Totsuka District, Yokohama — Completion: February 1987
Cost: ¥25 billion — Floorspace: 25,000 m^2

Sumitomo Bakelite Co., Ltd.: Utsunomiya Applications Research Facility
Utsunomiya, Tochigi Prefecture — Completion: September 1985
Cost: ¥10 billion

Sekisui Chemical Co., Ltd.: Electronic Applications Research Facility
Tsukuba, Ibaraki Prefecture — Completion: (April 1987)
Cost: ¥6 billion — Floorspace: 12,000 m^2

Sekisui House, Ltd.: General Dwelling Research Center
Seika-cho and Kizucho, Kyoto — Completion: (1990)
Cost: ¥5 billion — Floorspace: 50,000 m^2

Central Glass Co., Ltd.: Technical Center
Matsuzaka, Mie Prefecture — Completion: July 1986
Cost: ¥8 billion — Floorspace: 25,000 m^2

Takeda Chemical Industries, Ltd.: Tsukuba Research Facility
Tsukuba, Ibaraki Prefecture — Completion: July 1986
Cost: ¥6.7 billion — Floorspace: 9,500 m^2

Kyoka Hakko Kogyo Co., Ltd.; Takeda Chemical Industries, Ltd.; Mitsubishi Chemical Industries, Ltd.; Toray Industries, Inc.; Toa Nenryo Kogyo, KK; and nine other companies: Protein Engineering Research Facility
Chiri District, Osaka — Project start: Late March 1986 (Late 1987)
Cost: *¥5 billion — Floorspace: 5,000 m^2

Terumo Corp.: New Research Facility
Nakai-machi, Kanagawa Prefecture — Completion: (Spring 1989)
Cost: ¥30 billion (¥10 billion for land)

Toa Nenryo Kogyo, KK: General Research Facility--Research Building, Laboratory Building, Facility Expansion
Oi-machi, Saitama prefecture — Completion: (January 1988)
Cost: ¥5.5 billion — Floorspace: 10,800 m^2 (research building)
5,600 m^2 (laboratory building)

[figure continued]

[Continuation of Figure 2-2-2-32]

Tokyo Electron, Ltd.: General Research Facility
Nirasaki, Yamanashi Prefecture   Completion: June 1986
Cost: ¥5 billion   Floorspace: 7,300 m^2

Toshiba Corp.: Electrotechnology Center
Kawasaki, Kanagawa Prefecture   Completion: February 1987
Cost: ¥40 billion   Floorspace: 52,000 m^2

Toppan Printing Co., Ltd.: General Research Facility
Sugito-machi, Saitama Prefecture   Completion: July 1986
Cost: ¥5 billion   Floorspace: 24,800 m^2

Nikken Chemicals Co., Ltd.: Research Facility
Fukaya, Saitama Prefecture   Completion: (1988)
Cost: ¥5~6 billion

Nissin Food Products Co., Ltd.: Central Research Facility
Ritto-cho, Shiga Prefecture   Completion: (1987)
Cost: ¥6 billion   Site: 16,500 m^2

Nissei: Research Facility for No 3 Factory
Oikawa-machi, Shizuoka Prefect   Completion: (March 1987)
Cost: *¥6 billion   Floorspace: 7,000 m^2

Nippon Timesharing: General Systems Research Facility
Outskirts of Hamamatsu City   Construction start: (Spring 1987)
Cost: ¥15 billion   Site: 260,000 m^2

Chiba-Geigy (Japan), Ltd.: International Scientific Research Facility
Takarazaka, Hyogo Prefecture   Completion: (1989)
Cost: ¥9 billion   Floorspace: 7,000 m^2

Nippon Electric Co., Ltd.: Silicon Technology Development Center
Sagamibara, Kanagawa Prefecture   Completion: June 1985
Cost: ¥10 billion (FY 1985 only)   Floorspace: 3,000 m^2

Nihon Tokushu Noyaku Seizo KK: Research and Development Center--Expansion
Yuki, Ibaraki Prefecture   Completion: (1989)
Cost: ¥12 billion

Victor Co. of Japan, Ltd.: Kurihama General Research Center
Yokosuka, Kanagawa Prefecture   Completion: October 1986
Cost: ¥10 billion   Floorspace: 24,000 m^2

Nippon Yusen KK: (1) General Research Facility
(2) Technology Research Center
Completion: (1988-89)
Cost: *¥8 billion

[figure continued]

[Continuation of Figure 2-2-2-32]

Nintendo Co., Ltd.: Development Center
Downtown District, Tokyo — Completion: August 1985
Cost: ¥10 billion — Floorspace: 3,000 m^2

House Food Industrial Co., Ltd.: Research Facility (food technology research and training)
Chiba Prefecture — Completion: (1988)
Cost: ¥8.5 billion — Site: 50,000 m^2
(¥3.5 billion for land)

Hamamatsu Photonics: Research Facility
Hamamatsu, Shizuoka Prefecture — Completion: (1996)
Cost: *¥50 billion — Site: 16.3 ha

Fuji Xerox Co., Ltd.: System Technology Development Center
Iwase, Saitama Prefecture — Completion: February 1985
Cost: ¥20 billion

Matsushita Electric Industrial Co., Ltd.: VLSI Research Facility
Kadoma, Osaka — Completion: October 1985
Cost: ¥20 billion — Floorspace: 17,000 m^2

Mitsui Petrochemical Industries, Ltd.: New Technology R&D Center (Phase I)
Sodegaura-machi, Chiba Prefecture — Completion: October 1987
Cost: *¥10 billion — Site: 150,000 m^2
(including optical disk factory)

Mitsubishi Metal Corp.: Naka Atomic Energy Development Center
Naka-machi, Ibaraki Prefecture — Completion: June 1985
Cost: ¥5 billion — Floorspace: 66,000 m^2

Mitsubishi Heavy Industries, Ltd.; Mitsubishi Nuclear Energy Industries, Ltd.: Mitsubishi Tokai Fuel Development Center
Tokay-mura, Ibaraki Prefecture — Completion: November 1986
Cost: ¥10 billion

Mitsubishi Electric Corp.: New VLSI Development Building
Itami, Hyogo Prefecture — Completion: April 1986
Cost: ¥18 billion (approximate) — Floorspace: 8,800 m^2

Minebea Co., Ltd.: Development and Technology Center
Asaba-cho, Shizuoka Prefecture — Completion: (April 1987)
Cost: ¥8 billion — Floorspace: 9,000 m^2

Morinaga Milk Industry Co., Ltd.: New Research Facility
Zama, Kanagawa prefecture — Completion: (December 1988)
Cost: ¥10 billion — Floorspace: 16,000 m^2

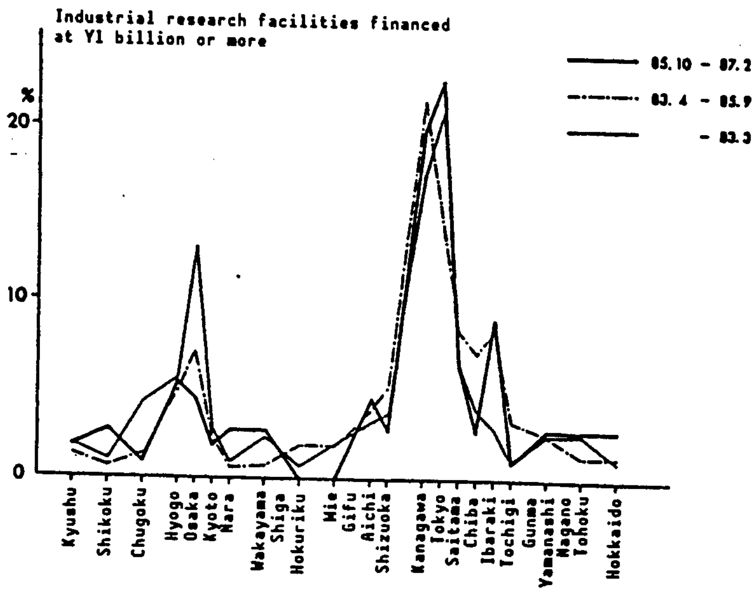
[figure continued]

[Continuation of Figure 2-2-2-32]

Ricoh Co., Ltd.: Central Research Facility		
Yokohama, Kanagawa Prefecture	Completion:	April 1986
Cost: ¥10 billion	Floorspace:	18,200 m^2

Note 1: Dates in parentheses ( ) under "Completion" indicate scheduled announcements. Asterisks * indicate that costs separated from plant costs are unknown.

Note 2: This table pertains to research facilities reportedly costing ¥1 billion or more to finance. It was prepared from data reported during the period January 1985-February 1987, accessed by means of the NEEDS-IR system of Nihon Keizai Shimbunsha.



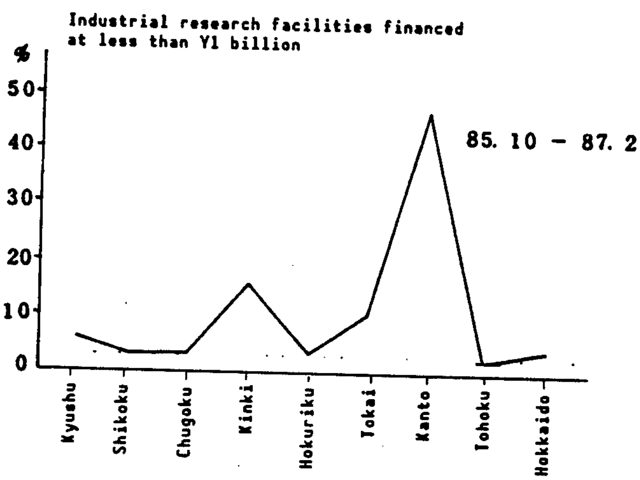


Figure 2-2-2-33 Research Facility Establishment by Region
Source: Survey of Agency of Industrial Science and Technology (March 1987)

C) Surveying the situation by region, roughly 60 percent of the companies with capital of ¥1 billion or more have their research facilities located in the Kanto area. This area offers a favorable R&D environment, being close to users and the area where research support industries are concentrated (Figure 2-2-2-33).

(7) Budding Research Industries

A) As we saw in the section on the leading edge of research and development, the priority given to R&D in private industry has risen (Figure 2-2-2-34), and the demand for various kinds of research support activities (services that perform or provide testing, evaluation, inspection, analysis, technological information, or research personnel) has rapidly increased (Figure 2-2-2-35) as R&D activities have become more complex and sophisticated, development competition has intensified, and trends toward moving into new fields and implementing cross-fertilization between fields have developed. There has now developed, in fact, what might be called the "research support industry."

B) As this has been happening, the area of research support activities--which used to be an in-house area--has become independent and grown into an industry in its own right. This research support industry is now making important contributions toward utilizing research personnel more efficiently, toward reducing the costs of testing, analysis, inspection, and prototyping, and toward handling information faster and better (Figure 2-2-2-36).

C) We are also witnessing the advent of another industrial grouping of companies which specialize in R&D work commissioned by other companies. We might indeed call this the "R&D industry." This industry has considerable growth potential as the volume of R&D work increases in private industry, as the quality of that work rises, and as greater emphasis is given to business specialization.

D) These trends are developing in the context of expanding Japanese research activity, and are indicative both of improved productivity as a result of R&D successes and of increased diversification and sophistication in research activities at companies which recognize the potential of new markets. What we are seeing, then, is the budding of a new industry--let us call it the "research industry"--which is made up of the "research support industry" and the "R&D industry" (Figure 2-2-2-37).

According to MITI calculations, the importance of the "intellectual areas of industry"--which include the "research industry"--is growing year after year. In terms of employment structure, and taking the production divisions of industry as a whole as 100, the percentage accounted for by the "intellectual areas of industry" (see note below) will grow from 54 percent in 1985 to 85 percent in the year 2000 (Figure 2-2-2-38).

Note: Intellectual areas of industry
1. High-level divisions in industry
   In-house R&D divisions, data processing divisions, etc.

Note: 2. Industrial support service industry
Research facilities, software industry, data processing service industry
Information service industry; Nondestructive testing industry, etc.

Answers

1. Company status of top managers of research divisions is rising.
2. Research divisions are being given more importance in terms of opportunities for rapid promotion.
3. Science and engineering graduates increasingly prefer placement in research divisions.
4. Increasing budgetary priority is being given to research funding over funding for other divisions.
5. The number of those being transferred from research divisions to production divisions with promotions is increasing.
6. An increasing number of company directors have had experience in research divisions.

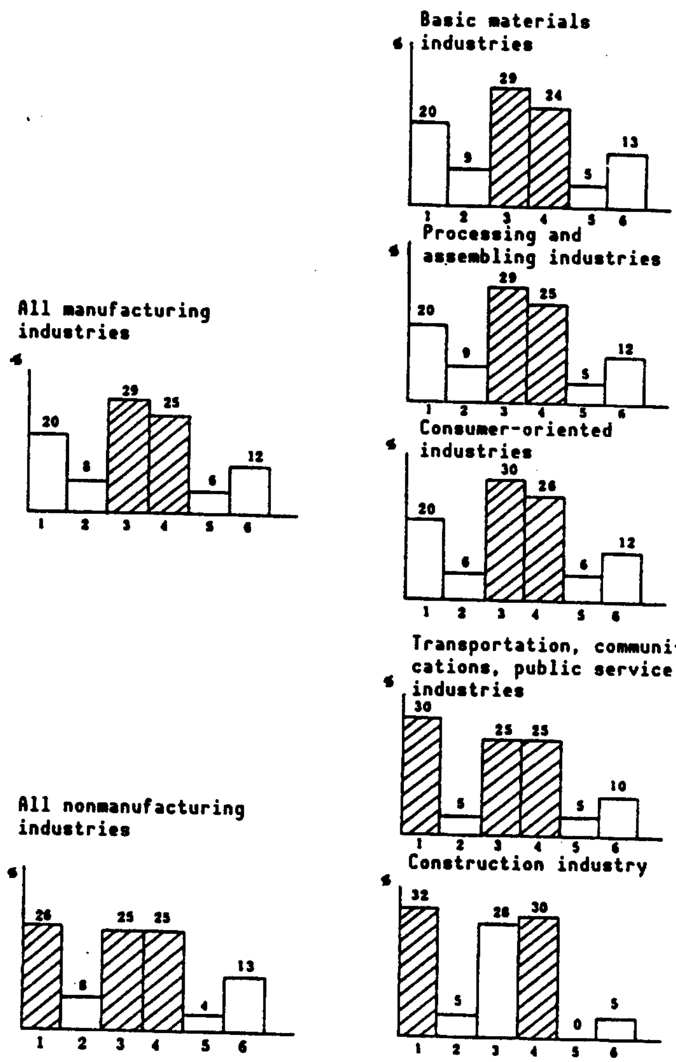


Figure 2-2-2-34 Trends in In-House Status of Research Divisions
Source: "Questionnaire Survey of Research Activities," Agency of Industrial Science & Technology (May 1988).

Support Function Classifications:

1. Production/supply of basic materials, experimental organisms
2. Production/supply of test instruments and equipment
3. Prototyping, trial production
4. Testing, analysis, rating
5. Information services
6. Supply of data processing hardware, commissioned data processing
7. Temporary assignment of R&D personnel to outside organizations
8. Equipment lease/rental, use of equipment loaned from outside
9. Other

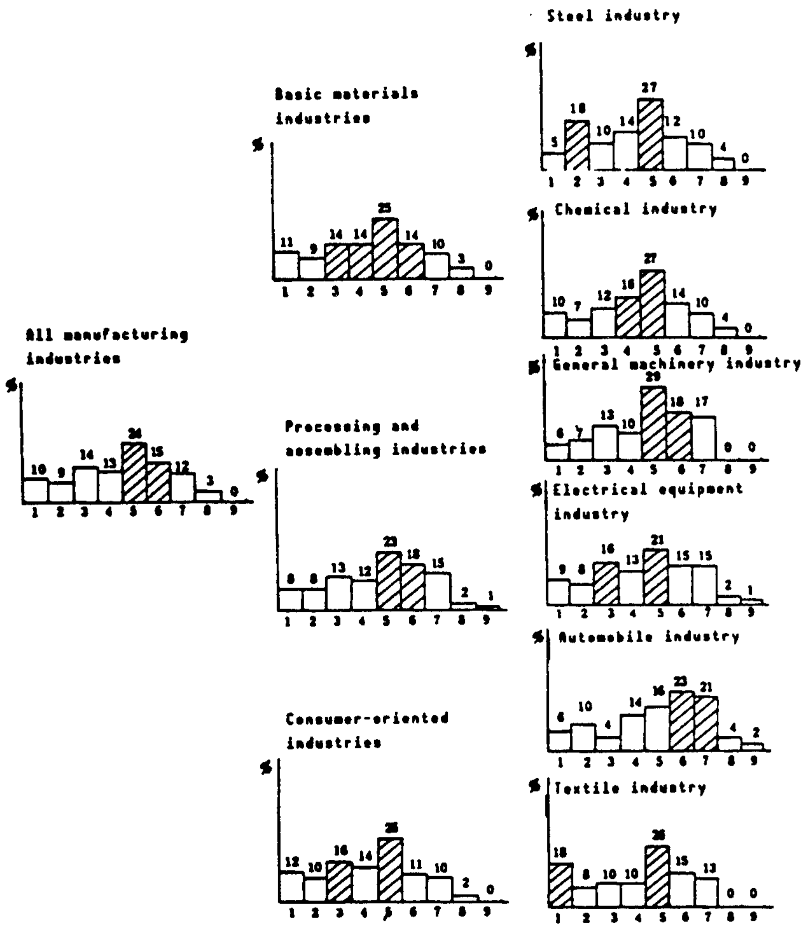


Figure 2-2-2-35 Support Functions of Future Importance

Source: "Questionnaire Survey of Research Activities," Agency of Industrial Science & Technology (May 1988).

a) Testing, Analysis, Inspection

Answers

1. Less expensive overall than in-house support operations
2. Level of support functions higher than in-house support
3. Can meet needs faster than with in-house support functions
4. Other

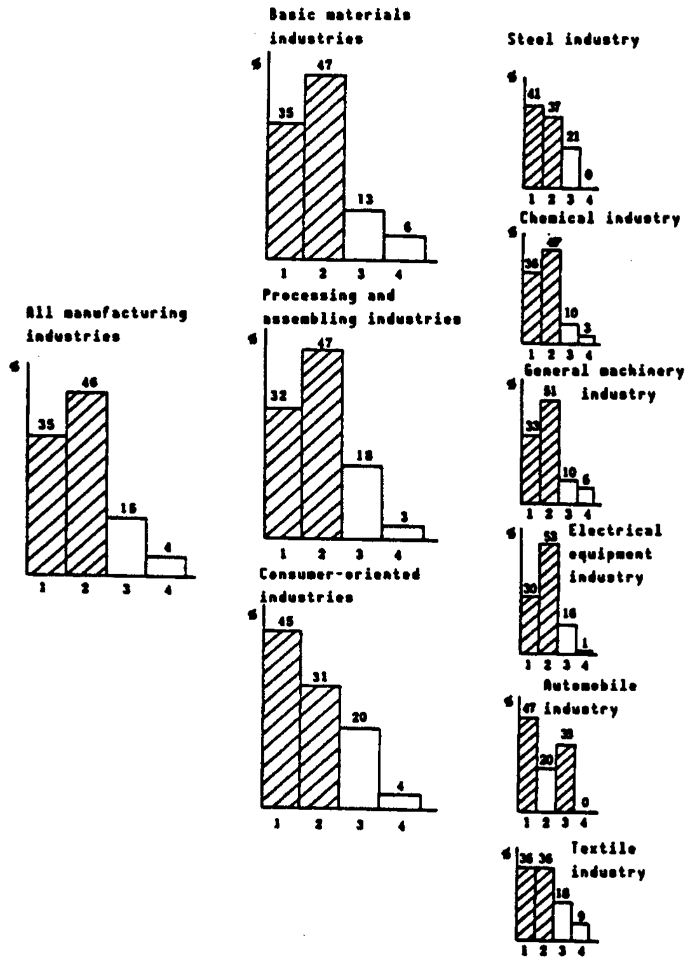


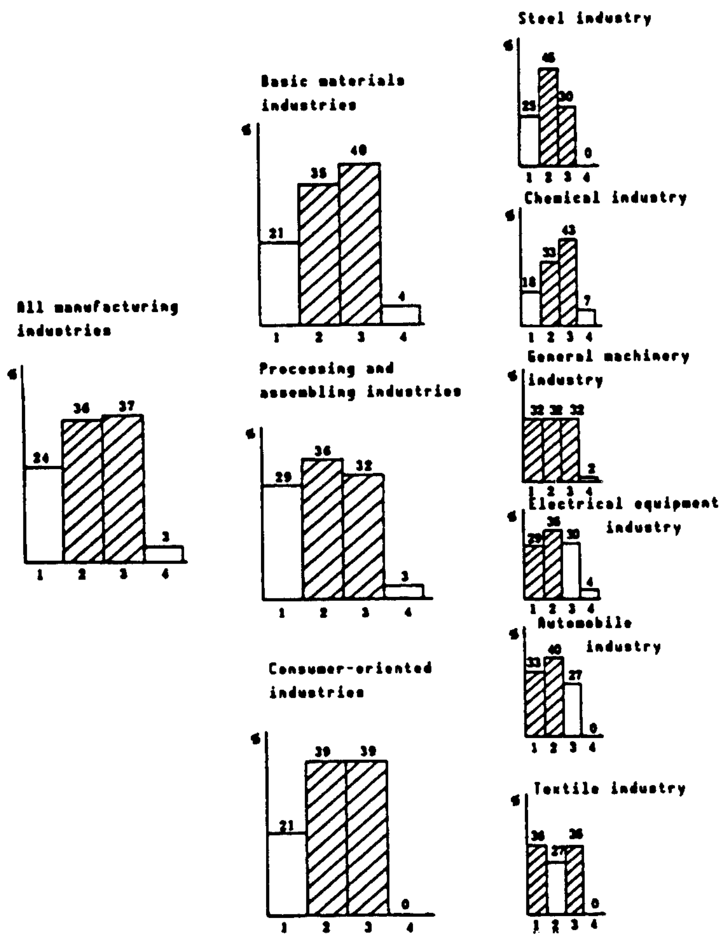
Figure 2-2-2-36 Advantages of Using Research Support Industries

[Continuation of Figure 2-2-2-36]

b) Data Processing

Answers

1. Less expensive overall than in-house support operations.
2. Level of support functions higher than in-house support.
3. Can meet needs faster than with in-house support functions.
4. Other



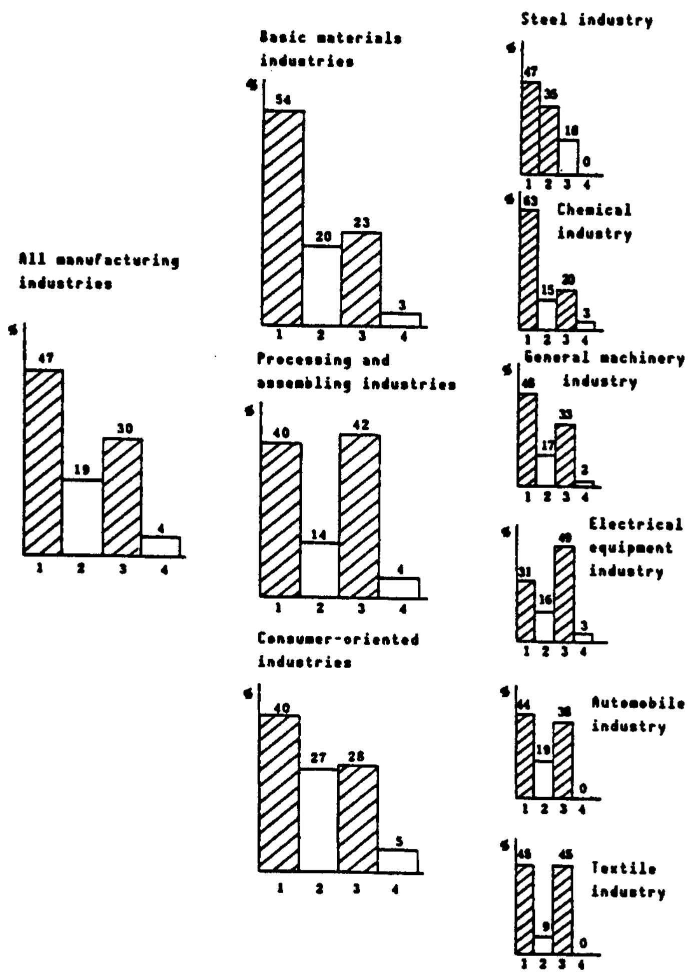
[figure continued]

[Continuation of Figure 2-2-2-36]

c) Prototyping, Trial Production

Answers

1. Less expensive overall than in-house support operations.
2. Level of support functions higher than in-house support.
3. Can meet needs faster than with in-house support functions.
4. Other



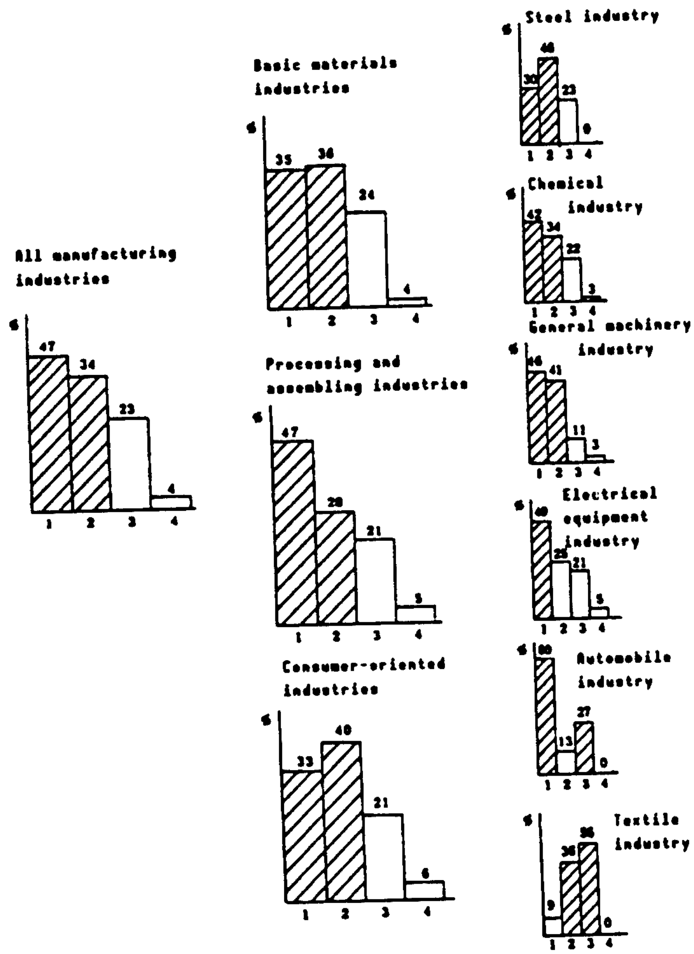
[figure continued]

[Continuation of Figure 2-2-2-36

d) Assigning Personnel To Work Temporarily in Other Organizations

Answers

1. Less expensive overall than in-house support operations.
2. Level of support functions higher than in-house support.
3. Can meet needs faster than with in-house support functions.
4. Other



Source: "Questionnaire Survey of Research Activities," Agency of Industrial Science & Technology (May 1988).

Research Industry

- Research Support Industry
  - Industries Engaged in R&D Work
    - Testing, Evaluation, Inspection, Analysis (Toray Research, Matsushita Technoresearch, KHI Analysis Center)
    - Information, Data Processing (Asahi Research, Daiya Research)
    - Research Facility Supply (Rigaku Denki Kogaku, Denki Kagaku Keiki)
    - Design, Prototyping (Trial Production) (Hitachi Electronic Engineering, Interface Giken)
    - Researcher Dispatching, Etc. (Meitech, Technobrain)
  - R&D Environment Support Industries
    - Surveying, Consulting (Mitsubishi Chemical Technoengineers, MCL)
    - R&D Personnel Training (Noritsu Kyokai [Efficiency Association])
    - Incubating, Etc. (Tsukuba Research Support Center, Nippon Incubation)
- R&D Industry
  - R&D Contractors (Independent R&D Companies)

    (Matsushita Giken, Toyota Central Research Labs, Future Technology Research Institute, Nichizo Tech, NTT Technology Transfer, Ebara General Laboratories, Misawa Home General Laboratories, Mitsui Eng & Shpbldg Akishima Research Facility, Fuji Electric General Laboratories)
  - Spun-Off or Externalized Company R&D Divisions

    (Mitsubishi Chemical Life Science Research Institute, Fujitsu Research Institute, Hitachi Central Laboratories, Matsushita Electric Central Laboratories, Toshiba Central Laboratories, NEC Development Group, Sharp Technology Center, Nippon Steel Central Research Center)

Figure 2-2-2-37 Outline of Research Industry

Source: Agency of Industrial Science and Technology

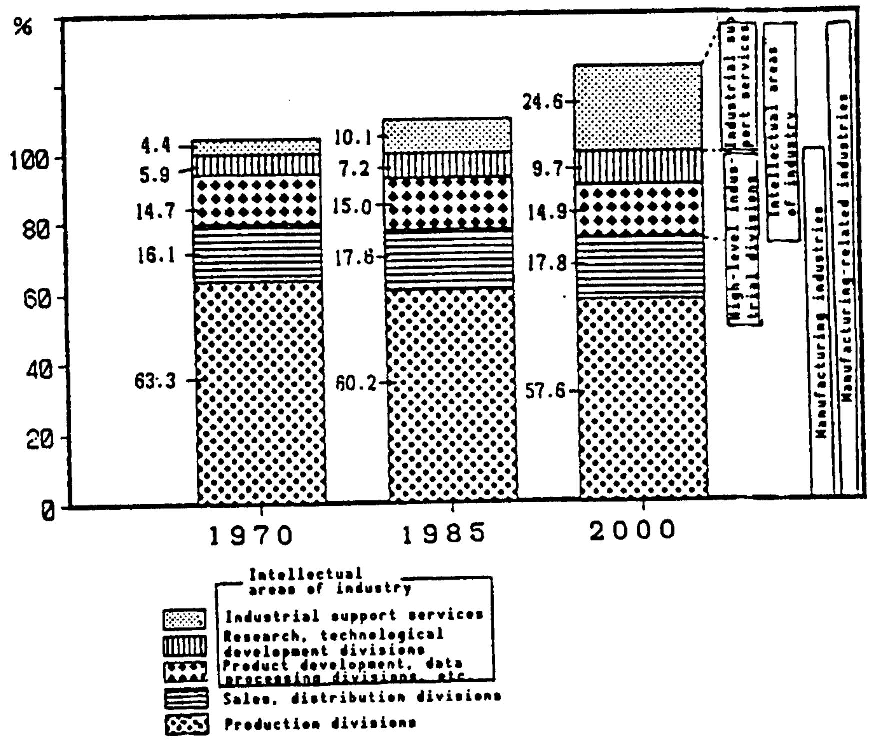


Figure 2-2-2-38 Growing Priority Given to "Intellectual Areas of Industry" in Context of Employment Structure

Source: MITI

E) Hopes are strong in the industrial community that policies supportive of the "research industry" will be implemented. Such policies would include, for example, measures to better facilitate the joint use of research facilities, the provision of tax incentives, and the setting up of improved institutions and programs to promote joint research between industry, universities, and government agencies (Figure 2-2-2-39).

F) This industry is expected to grow even more in the future, but there is a perceived need to integrate more of the "intellectual areas of industry" --now concentrated heavily in the greater Tokyo region--into regions throughout the country. To promote such integration, legislation has been passed, namely the "Act To Promote Regional Integration of Specific Industries To Raise Level of Regional Industry [Chiikisangyo no Kodoka in Kiyo suru Tokutei Sangyo no Shuseki no Sokushin in Kansuru Horitsu]." This legislation provides for the development of more commercial sites where research facilities can be built, and for funding and tax incentives for establishing R&D facilities which can be jointly used. The future trends in the establishment of "research industry" facilities in regional areas will be watched closely.

Answers

1. Increased subsidization
2. Tax incentives
3. Financing for technology promotion (low-interest loans from Japan Development Bank, etc.)
4. Promotion of joint research (including joint projects involving industry, universities, and government offices)
5. Active utilization of support industries by national and public research organizations
6. Effective use of national and public research organization facilities
7. Policies for promoting database creation
8. Policies for promoting development of specialists
9. More positive steps to enhance intercommunications between industry, universities, and government agencies

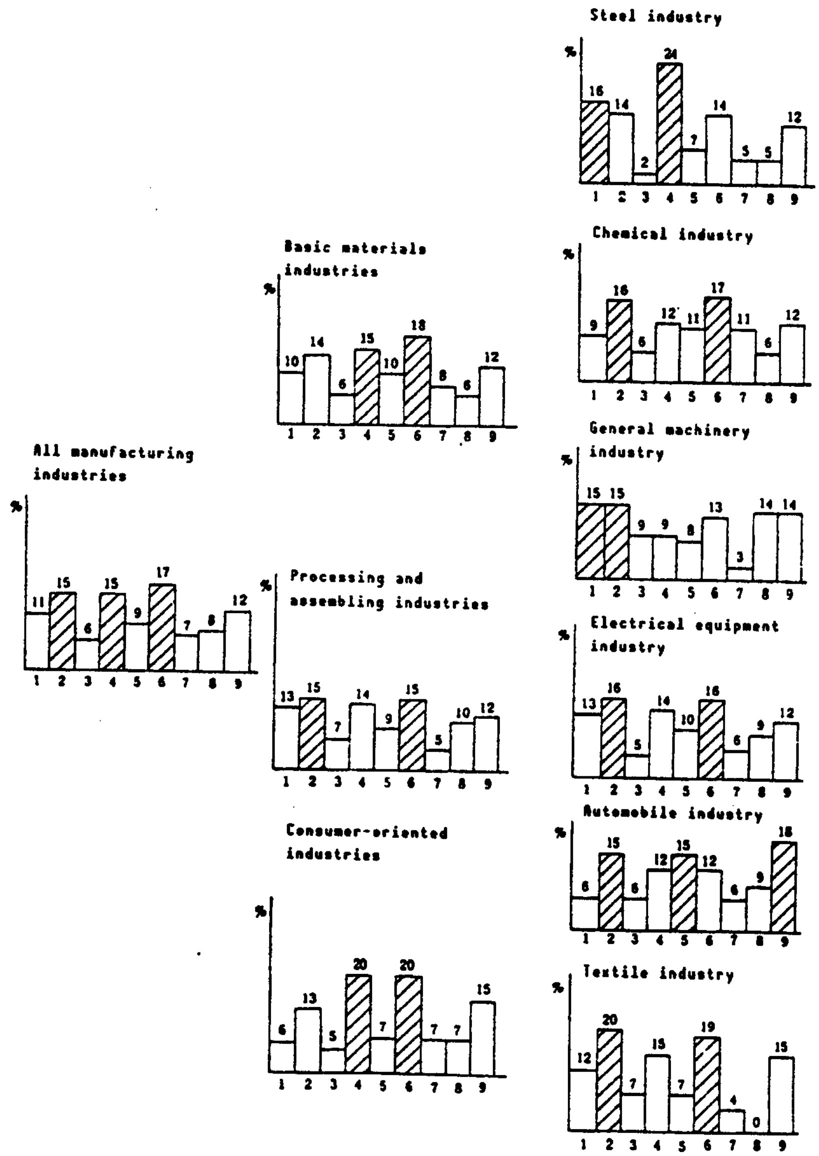


Figure 2-2-2-39 Policies for Upgrading Research Support Functions, Research Support Industries [figure continued]

[Continuation of Figure 2-2-2-39]

Source: "Questionnaire Survey of Research Activities," Agency of Industrial Science & Technology (May 1988).

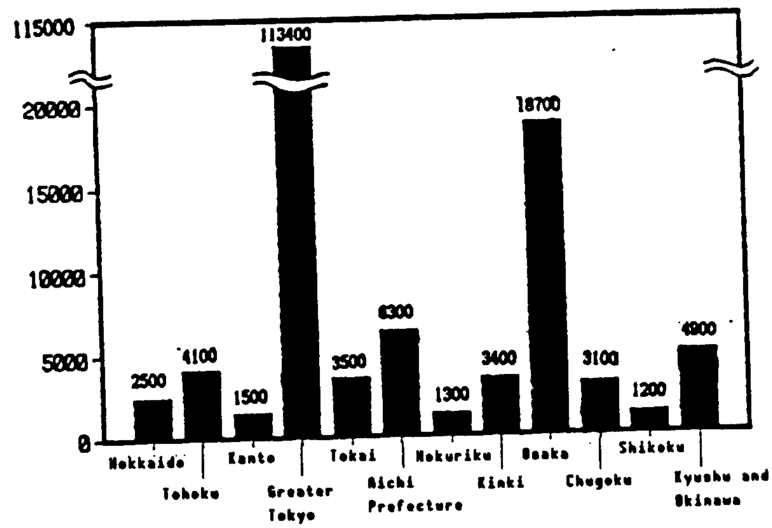


Figure 2-2-2-40 Industrial Support Service Industry--Sales by Region

Source: MITI

Chapter 3. Japanese Industrial Technology--Problems, Direction

Section 1. Japanese Industrial Technology--Comprehensive Evaluation, Problems

In the preceding chapter we examined the status of Japan's industrial technology and the leading edge of industrial R&D, from a number of perspectives. Now, based on these findings, we wish to attempt a comprehensive evaluation of Japanese industrial technology, and then address the issue of what roles Japan should now play in the area of industrial technology after becoming one of the strongest economic powers in the world.

1. Comprehensive Evaluation of Japan's Industrial Technology

(1) Current Status

1) Technology Level

(A) The following characteristic observations may be made concerning the level of Japanese industrial technology.

<1> In conventional products, the level is already near or at the top levels in the world. This is particularly so--for the 10 years studied in this survey--in the process and assembly industries.

<2> The technology level has also risen in high-tech products in the 5 years in which that segment has been surveyed, and is at or near the highest levels in the world in quite a number of areas. Japan is somewhat behind the world leaders, however, in areas requiring applications of total systems technology.

<3> The rises in technology level noted above are backed up by the accumulated knowledge gained from continual research and development. In the area of advanced basic research, however, which will provide the mainstays of the next century, Japan's technology still lags behind, when compared to the levels attained in conventional and

high-tech products. This is true even though world-class levels have been reached in some areas.

(B) Accordingly, the research levels in advanced basic technological fields are, at the current time, relatively retarded, compared to the high levels attained in conventional and high-tech products, even though high levels have been achieved in certain individual element technologies.

2) R&D Support Base

(A) R&D Investment

R&D investment, thanks to the investment enthusiasm of the Japanese private sector, is near the top levels in the world overall. Government R&D investment is low, however, and, partly for that reason, the ratio of research funding devoted to basic research is low.

(B) Research Personnel, Research Environment

<1> Compared to Europe and America, Japan has many researchers, but the ratio of those holding masters or doctoral degrees, who are assumed to possess sophisticated research abilities, is low. Compared to the number of engineering-oriented researchers, moreover, there are few science-oriented researchers. Hence the training of personnel for basic research is far from adequate.

<2> Furthermore, compared to Europe and America, Japan has few research assistants, and Japan's R&D expenditure per researcher is low. Combining these factors, we see that the infrastructure of Japanese research is weak.

<3> The international exchange of researchers is believed to be an effective way to promote more active and effective research, but this is being done to a much lesser extent in Japan than in the United States and elsewhere. Organizational rigidity has been blamed as a contributing factor.

(C) Research Support Structure

Japanese research facilities are believed to be at least on a par with those of Europe and America, in terms of the standard research equipment which is available and the condition it is kept in. Nevertheless, Japan lags behind when it comes to the large-scale research facilities that are essential to serious, large-scale basic research. Japan has also fallen behind in other aspects of its research infrastructure, including data bases and the ready availability of standard substances.

3) Internal Technological Exchange

(A) Technology Transfer, Acquisition

<1> The proportion of R&D expenditure going toward technology acquisition is declining with each passing year. This is reflective of an intensification in R&D activity in Japan.

<2> The volume of technology transfers, meanwhile, is growing steadily overall. In terms of the number of new contracts concluded annually, technology transfers have continually outstripped technology acquisitions since 1972.

<3> Most of the technology acquisitions are from Europe or America, while most of the technology transfers are directed toward Asia or the United States.

(B) Researcher Exchange

Roughly three out of four Japanese researchers who receive overseas assignments are sent to one of the advanced nations of Europe or America, with about half of those going to the United States (1986 figures). Of those foreign researchers receiving assignments in Japan, however, only some 15 percent or so come from the advanced nations, with the majority coming from the developing nations. Much of the technology transfer to the developing nations is done through the mechanism of receiving researchers into Japan from those nations.

(C) Research Information Exchange

The number of Japanese scientific papers being published in the major scientific journals is growing rapidly, but the number of papers published per capita is small and the rate of their citation is low. Hence the level of dissemination of research information is low compared to the advanced western nations.

(D) International Joint Research

The government is aggressively forging policies and creating programs to promote international joint research, such as the Human Frontier Science Program and the International Research Cooperation Program. In the industrial sector, the joint research being done with foreign companies is increasing, and there is an upward trend in industrial cooperation of the private level.

(2) Currents at Leading Edge of R&D in Industrial Technology

(A) Leading Edge of Basic Research

<1> At the leading edge of the basic research being carried on primarily at national research facilities, basic and creative in-depth research and development is being pursued at a rapid tempo, particularly in such basic scientific research areas as the following:

<a> Elucidation of relationship between molecular and atomic structure of substances, on the one hand, and their behavior and functionality on the other; research on ways to control molecular and atomic structure

<b> Elucidation of reaction mechanisms in living organisms; elucidation of relationship between protein structure and protein function

<c> Elucidation of brain functions as they relate to human language, knowledge, thought, and skills

<2> There is an interesting phenomenon occurring in these fields of research and development. It might be called the "science-technology merging-resonating phenomenon." It is in this context that we are now beginning to perceive the technological development tasks which must be done in order to generate further technological innovation and to foresee the directions in which future breakthroughs should be made.

(B) Leading Edge of Industrial Technological R&D in Private Industry

<1> At the leading edge of research and development in private industry, R&D is intensifying in basic research areas as well as applications research. The major objectives of this research, in most industries, are to move into new business fields, to diversify business operations, and to make products more highly functional. The R&D being done on high-tech products includes efforts to control substance structure at the molecular and atomic levels, to achieve extremely high precision in machine processing, and to make products and systems more knowledgeable and intelligent. In general, however, most of this "basic research" is geared toward developing new applications, and little work is being done to delve into areas of basic scientific research. There are signs that more and more joint research is being done in order to promote such research as noted above, including projects involving cross-industry cooperation with domestic and foreign companies.

<2> Reflective of the situation described above are the following characteristic trends now observed in the R&D efforts being made in Japanese industry

<a> Strengthened R&D commitment as seen in increased R&D investment

<b> Shift in research content toward basic research

<c> Greater efforts to acquire various human resources

<d> Diversification of fields targeted for R&D

<e> Implementation of international joint research and technological tie-ups

<f) Establishment of research facilities devoted primaryly to basic research

<g> Formation of research support industries

(C) Against the background of this phenomenon of merger and resonance between science and technology, Japanese industry is now forging ahead rapidly with R&D that reaches down to the levels of basic research, although there are differences between the depth of the work being done at the national laboratories and in private industry.

(D) The encouraging movements in the technological development in private industry are hampered, however, by the following problems and obstacles:

<1> Although in a few industries R&D investment is now beginning to outstrip investment in plant and equipment, this situation is destabilized by a number of factors, including the fact that R&D investment is very sensitive to fluctuations in the economy.

<2> In terms of the content of research, there is a limit to how involved private industry can become in basic research, particularly in those areas which are extremely risky.

<3> The acquisition of research personnel, both in qualitative and quantitative terms, is becoming a matter of urgent concern.

<4> It is difficult for the research support industry to build laboratories and other facilities in regional areas for their research support operations.

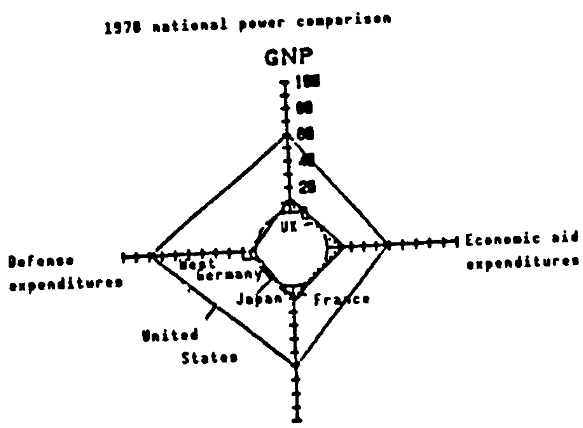
<5> How to effectively cope with on-going internationalization in R&D related to industrial technology is an increasingly serious problem.

2. Japanese Industrial Technology at Turning Point

(A) As Japan's economic power and technological prowess have risen, the role which Japan must play, in basic technological fields as well as in the application-oriented and developmental areas of industrial technology, has grown. This is important in the interest of achieving harmonious growth in the world economy and healthy development in science and technology. The entire world now looks to Japan with greater expectations than formerly (Figures 3-1-1, 3-1-2).

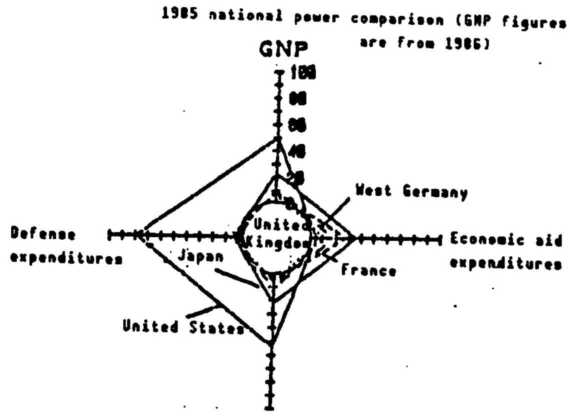
(B) In the Western nations, policies of improving [national] competitiveness are being aggressively implemented. These policies focus on science and technology and are specifically designed to promote the industrialization of the fruits of basic research and other R&D efforts.

(C) In the United States there have been a number of reports such as the so-called Young Report of the Presidential Committee on Industrial Competitiveness and the New Young Report of the Council on Competitiveness, which have pointed to such structural changes as the decline in industrial technological development ability due to the growth of overseas production and R&D centers, and the observable decline in technological spin-off to the consumer sector as a result of R&D efforts focused on defense-related technology and "big science." These reports, while recognizing that the transition from basic research success to manufacturing technology is not always smooth, do mark out strategies for making the United States more competitive, such as providing greater protection for intellectual property, moving ahead with the development of superconductivity, and promoting technology transfers from basic research findings to production technologies. Also dealt with in these reports is the national security aspect of advanced technology (Figures 3-1-3, 3-1-4).



1970	G N P	Economic aid expenditures	R&D expenditures	Defense expenditures
United States	59.8	49.3	61.3	79.5
United Kingdom	7.4	9.9	7.4	6.5
West Germany	11.6	11.6	13.1	8.9
France	9.1	14.6	7.4	5.4
Japan	12.1	14.5	10.7	1.7
Total for big five	100	100	100	100

Figure 3-1-1A National Power Comparison Between Five Leading Industrial Nations--1970



1985	G N P	Economic aid expenditures	R&D expenditures	Defense expenditures
United States	50.1	5.6	54.6	79.0
United Kingdom	7.2	11.7	4.7	7.8
West Germany	10.7	10.3	11.5	4.6
France	6.7	26.3	6.4	4.6
Japan	23.4	35.9	22.7	3.9
Total for big five	100	100	100	100

Figure 3-1-1B National Power Comparison Between Five Leading Industrial Nations--1985

Source: "Interim Report of Research Committee on Asian-Pacific Trade Development (ARTAD)," MITI

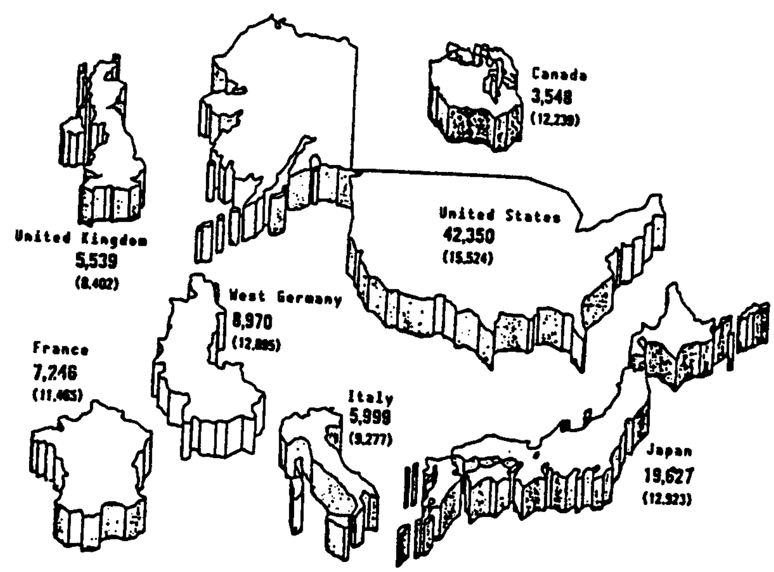


Figure 3-1-2 Comparisons of Gross National Product (GNP) or Gross Domestic Product (GDP), National Per-Capita Income--Summit Nation (National per-capita income indicated in parentheses) (1986, GNP (GNP) unit - $100 million, per-capita income unit - dollar)

Source: "Japan and Toronto Summit" Japan Economic Training Center

Report of Presidential Committee on Industrial Competitiveness (1/85)
--New Realities of Global Competition

(1) New R&D tax incentives
(2) Improvement of manufacturing technology, merchandizing new technology
(3) Better protection for intellectual property
(4) Increased capital and human resources

OTA Report (4/86)
--Intellectual Property Rights in Electronic Information Age

(1) New technologies for generating, distributing, and using information represent a fundamental change that compares to printing technology
(2) Need to completely reform the intellectual property rights system during the coming 10 years
(3) Setting up of mechanism to evaluate the functions of and trends in the intellectual property rights system

President Reagan's Competitiveness Initiative (1/87)
--White Paper: Challenges to U.S. Competitiveness

(1) Advocating a strong United States
(2) "Strengthening competitiveness" as a means of coping with rising "protectionist" pressures
(3) Creating new knowledge in advanced technological fields; influence on markets
(4) Building up of national human-resource base in science and technology

Council on Competitiveness Report (New Young Report) (4/87)
--Competitiveness Crisis: Facing the New Realities

(1) Strengthening competitiveness our foremost national task
(2) Declining U.S. competitiveness
(3) Need commitment and involvement by all Americans

Promising Advanced Technologies (Department of Commerce Report) (6/87)
--Emerging Technologies: Economic and Technological Assessment as We Face the Year 2000

(1) Obstacles to achievement of maximum economic success from the perspective of new technology
(2) Recommendations for overcoming obstacles
- Reduction of capital costs
- Tax incentives, etc.

Figure 3-1-3 Related Policy Trends in the United States
[figure continued]

[Continuation of Figure 3-1-3]

President Reagan's Superconductivity Initiative (7/87)
--Guarantee of U.S. Industrial Technology Brought About by Scientific Progress

(1) Upgrading programs for cooperation between industry, government, and the universities
(2) Promotion of transfers of scientific achievements to private sector
(3) Protection of intellectual property

Study of President's Superconductor Competitiveness Bill (2/88)
--Promotion of inventions in superconductivity field, rapid realization of commercial applications

(1) Broadened application of Joint Research Act (joint R&D, including joint-production ventures)
(2) Stronger patent protection for manufacturing processes
(3) Exemption from disclosure obligations for research findings at governmental research facilities when there is a danger of lowering industrial competitiveness

Senate passage of Biotechnology Commercialization Promotion Bill (6/88)
--Strengthen international competitiveness in field of biotechnology

(1) Form new organization to draft commercialization strategies
(2) Form new organization to promote research information utilization

Enactment of Omnibus Trade Act (9/88)
--Strengthen competitiveness of U.S. industry, promote manufacturing technology transfers

(1) Formation of National Standard Technology Research Institute (restructuring of NBS, promotion of research in manufacturing technologies)
(2) Establishment of manufacturing technology transfer regional centers, regional information centers
(3) Plan advanced technology projects, promote commercialization
(4) Conduct technological surveys on semiconductors, fiber optics, superconductivity
(5) Assure asymmetrical access to technological research

1. New Materials

(1) Ceramics (ceramics for highly functional structures, ceramics for electronic equipment) Rank - B
N: Improved weight-to-strength characteristics at high temperatures
P: Heat engines, turbine blades, thermal insulation
I: Automobile, aircraft engines
N: Improved insulative properties and optical characteristics
P: Electronic equipment boards, optical integrated circuits
I: Materials for electronic equipment

(2) Mixed Polymers (plastic polymers reinforced with high-strength fibers)
Rank - A
N: Improved specific weight-to-strength
P: Structural materials
I: Constitutions for aerospace and automotive industries
N: Design elasticity for three-dimensional asymmetry
P: Structural materials

(3) Metals (quick-cooling solidification, metal matrix mixtures)
Rank - C
N: Improved strength and high-temperature characteristics
P: Structural materials, superconductor materials
I: Processed or machined materials
N: Improved magnetic properties
P: Electromagnetic equipment
I: Electronic equipment

2. Electronics

(1) Advanced Microelectronics Rank - A
N: Improved speed and size characteristics
P: Semiconductor devices
I: Electronic materials, systems
N: Improved magnetic characteristics
P: Data accumulation
I: Data processing

(2) Optoelectronics (fiber optics and optical wavelength processing)
Rank - A
N: Improved speed, size, capacity, and safety characteristics
P: Facilities for electronic equipment, data processing
I: Communications, computers
N: High-density data accumulation
P: Computer systems of alls sizes
I: Computers

Figure 3-1-4 Advanced Strategic Technologies Oriented Toward Year 2000
(U.S. Department of Commerce, June, 1987)
New Technologies and Their Economic Impact
[N: Newness, progressiveness; P: Product/process applications;
I: Industrial applications] [figure continued]

[Continuation of Figure 3-1-4]

(3) **Milliwave Technology** Rank = C
- N: Replace radio systems; use RF spectrum for other applications
  - P: Voice and data communications
    - I: Telecommunications carrier, joint use for private lines

3. Automation

(1) **Manufacturing Industries (computer integration, flexible computer systems)** Rank = A
- N: Flexible alteration of manufacturing processes
  - P: All manufacturing processes
    - I: All manufacturing processes
- N: Centralized control of all manufacturing operations

(2) **Business and Office Systems (intra-organizational computer applications)** Rank = B
- N: Efficient data accumulation, retrieval exchange
  - P: Network, word processing, database management
    - I: All organizations

(3) **Technical Services (computer applications in preparing commercial services)** Rank = B
- N: Efficient accumulation, retrieval, exchange of large volumes of data
  - P: Data retrieval and distribution, database management, training
    - I: Financial services, electronic mail, telecommunications, specialist services

4. Biotechnology

(1) **Genetic Engineering (design, manufacture of highly selective agents)** Rank = A
- N: Improved diagnostic preparations and therapeutic drugs
  - P: Health services
    - I: Pharmaceuticals, preparations
- N: Improved plant, agriculture chemical, and animal supplements
  - P: Foods, agriculture chemicals
    - I: Agriculture, food processing
- N: Neutralization of pollutants
  - P: Environmental control processes
    - I: Chemical industry, chemical processing and treatment

(2) **Biochemical Processing/Treatment** Rank = B
- N: Improved biochemical processes and yield control
  - P: Chemical separation, reactor biosensors
    - I: Chemical industry

[figure continued]

[Continuation of Figure 3-1-4]

5. **Computers**

(1) **Computer Hardware (supercomputers, parallel processing, computer architecture)** Rank - A
N: Improved computing speeds, reduced costs
P: Data processing, computer control
I: Possibilities for all fields

(2) **Artificial Intelligence (including expert systems, natural languages, robotics)** Rank - B
N: Improved computer duplication of human decision-making ability
P: Data processing, computer control
I: All applications in which computers are used

6. **Medical Technology**

(1) **Pharmaceuticals (other pharmaceuticals included under "4. Biotechnology"** Rank - B
N: Improved processing with treatment systems
P: Magnetic resonance photography, CAT scan, radiation treatment
I: Medicine

7. **Thin Film Technology (Applications for semiconductors included with Electronic Engineering)**

(1) **Surface and Interface Technology** Rank - C
N: Improved control of and yield from chemical reactions
P: Chemical catalysts
I: Electronic equipment, computers

(2) **Film Technology** Rank - C
N: New chemical properties, improved chemical separation techniques
P: Chemical separation
I: Chemical engineering, food processing

Notes: The rank (A, B, C) indicates the economic impact, with "A" being "strong" and "C" being weak.
Superconductivity was considered a "potential new technology" and excluded from the evaluations.

Source: "The Status of Emerging Technologies," DOC, 6/9/1987.

(D) Efforts are also being made by European countries to enhance their competitiveness in industrial technology. Examples of these efforts are the "Framework Project" that outlines science and technology policies for the Common Market community, and the French-initiated "Eureka Project" for cooperating in the development of advanced technologies among the European nations (Figure 3-1-5).

A) **Framework Project--EC Technological Development 5-Year Plan--**

a. Reinforcement of scientific technological infrastructure of European industry, getting and keeping national competitiveness
b. Implementation of separate projects in each of eight scientific technological fields, including information and communications, biotechnology, and energy, in the 5 years of 1987-1991, with a total budget of ECU 5,396 million.

a) Esprit Project--Information Technology Development Project--
  I This is a project that was launched in February 1984, by the EC, for the purpose of catching Europe up in the field of information technology. It was followed in succession by Esprit II.
  II 50 percent aid. Aid amount of ECU 750 million for 1984-1988 (5-year plan). The aid amount (scheduled) for Esprit II in 1987-1991 is ECU 1.6 billion.
  III Participants: Companies, universities, research organizations
b) Bright Project--Joint R&D Project for Basic Technology and New Technology Applications--
  I EC launched this project in 1985 as a joint R&D initiative to aid industry
  II Budget: ECU 185 million
  III 103 cases determined in 198, 112 cases added in September 1987
c) Euram Project--European Advanced Materials Research--
  I Development of metallic materials, structural ceramics, and composite materials to assist in enhancing European industrial technology
  II Project Phase 1 (87-91): ECU 30 million in EC subsidies
  Project Phase 2 (starts 1989): ECU 220 million in EC subsidies (scheduled)
d) Race Project--Development of High-Level European Communications--
  I Creation of technology for comprehensive wide-area communications (IBC)
  II Project Phase 1 (87-91): Basic technology development; subsidy amount = ECU 550 million (50 percent subsidization)

B) **Eureka--Advanced Technology Development Project--**

a. Joint European project designed to close the gaps in high-tech fields and unify the European market (19 countries participating, plus EC committee) (proposed by France in April 1985)
b. 232 projects decided on by 1987.
c. Outside (i.e. non-EC) countries not excluded. South Korea showing interest.

Figure 3-1-5 Related Policy Trends in Europe

(E) Meanwhile, the entire world is now ardently hoping for the advent of a new technological revolution. To spark such a revolution, many believe that it is necessary to achieve a synthesis of scientific discovery and invention, on the one hand, and technological know-how, on the other, in a kind of mutually stimulating symbiosis. To realize such goals will, of course, require the full utilization of advanced technologies in pursuing R&D activities, but it also calls for firmer commitments to basic and creative research in order to precipitate further scientific discovery and invention.

(F) Accordingly, it has now become increasingly incumbent upon Japan to take the lead in basic and creative research, and to make greater international contributions by putting to good use the associated processes, results, and spin-off effects.

(G) Japanese R&D activities have enjoyed prodigious growth, particularly in areas of applications and development. Japanese industrial R&D has now come to a turning point, however, and Japanese companies must hereafter 1) strengthen their efforts in basic and creative research, and 2) make stronger commitments to making international contributions.

Section 2. Meeting Challenge of "Technological Revolution To Carry Us Through the 21st Century," International Contributions

1. Meeting Challenge of "Technological Revolution To Carry Us Through the 21st Century

(A) What might be called a "technological revolution to carry us through the 21st century" is desperately needed in order for Japan to tackle the two great tasks now facing it in this time of transition--namely the intensification of basic and creative research efforts and contributing to the international industrial community. Such a revolution would entail efforts to resolve the global problems now facing us as we approach the next century (which were discussed in Chapter 1). It would provide the driving force needed to realize even greater social and economic sophistication throughout the world. And, building on the foundation of new scientific discoveries and inventions, it would produce a train of new technologies. This is something which should be carefully considered.

(B) In the 1980's we have already identified many R&D themes and areas where breakthroughs are needed which may possibly lead to the "technological revolution to carry us through the 21st century," particularly in the fields of new materials, electronics, and biotechnology.

(C) What is most needed today is to plant and nurture such new budding technologies and to deal with the various problems that now need to be addressed at the global level. We saw in Chapter 2 that science and technology have recently begun to merge and to exhibit a resonance phenomenon. In this context, Japan too, at the leading edge of industrial research and development, is now becoming more actively involved in such basic and creative research as will lead to new scientific discoveries and inventions, in addition to making full use of its world-class advanced technologies in tackling such R&D tasks.

(D) It is now widely recognized that by taking on such R&D tasks, moreover, Japan will be able to make tremendous international contributions as a result of 1) conducting such R&D efforts, 2) the fruits realized therefrom, and 3) the resulting spin-off effects.

2. Meeting Challenge of Technological Revolution, International Contributions

(A) If we think about the rising expectations for such a new technological revolution and the promising signs recently being seen at the leading edge of industrial technological R&D, we will surely conclude that the greatest tasks now facing Japan, in terms of promoting industrial R&D, are those of taking the lead in working to achieve the "technological revolution to carry us through the 21st century," learning from the process of doing so, and taking advantage of the results and the spin-off effects realized from those results, as well as the task of working even more assiduously in making international contributions.

(B) In taking up the challenge of such a technological revolution, it will be necessary to engage in basic and creative research, focusing on fundamental and radical R&D tasks. It will also be necessary, however, to work toward the formation of internationally open R&D environments. This coincides with the awareness that Japan's industrial technology is now at a turning point, as discussed in Chapter 1.

(C) Such R&D efforts, moreover, will help to effect a better balance, both in the area of Japan's own research and development, and in terms of international technological exchange. This will require a more thorough-going commitment to basic and creative research, with respect to the former area, and a shift toward supplying more advanced knowledge, information, and technology, with respect to the latter. This will promote a weight transfer so that Japan will move away from being a mere "processing center," and gain international recognition as a "creative knowledge center."

In this context, it is believed that Japan's national testing laboratories will take on an increasingly important role as they function to bridge the gap between basic scientific research areas, on the one hand, and those research areas which are relatively more applications oriented, on the other.

(D) At the same time, we must not forget to respond to the rising expectation that Japan will contribute more substantively to the international community through its technological prowess in applications and developmental areas.

<1> More recently, the results of Japanese basic research have been effectively extended to production technology and products, primarily in Europe, and these applications have been widely spread throughout the world.

This phenomenon is being seen in terms of a secondary innovation function and proliferation function.

<2> In view of Japan's superior production technology, demand is growing among the developing nations for technological aid. According to the results of a questionnaire survey conducted by the Japan International Cooperation Agency (JICA) among ordinary citizens of a number of developing countries, an overwhelming number of those surveyed expected Japan to behave as a "leader in technological development" (Figure 3-2-1).

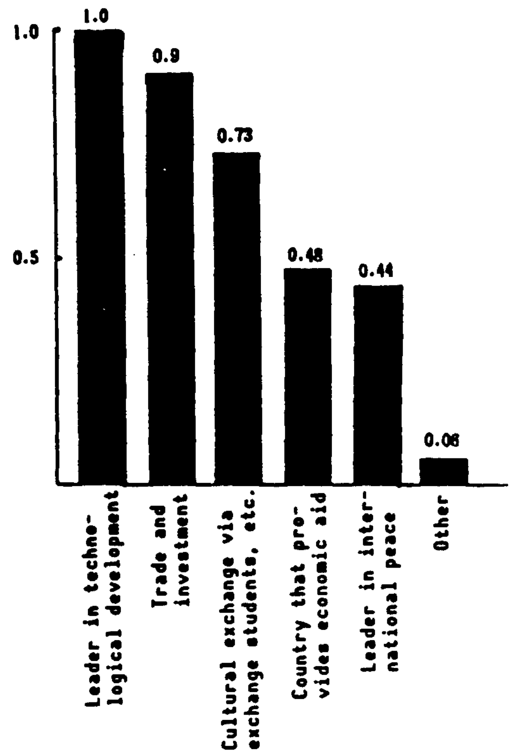


Figure 3-2-1 Global Expectations Regarding Japan's Role (taking "leader in technological development" as 1)

Source: KOKUSAI KYORYOKU [INTERNATIONAL COOPERATION], August 1988

3. Priority Fields for Achieving "Technological Revolution To Carry Us Through the 21st Century"

(A) In working toward the "technological revolution to carry us through the 21st century," it is essential that we clearly identify which R&D fields and R&D tasks ought to be given priority. In so doing, the following factors need to be kept in the forefront of our minds.

<1> Expectations for Technological Revolution Leading Toward 21st Century

a. Resolution of global problems (food, natural resources, energy, global environmental problems, etc.)

b. Improvements in society and quality of life

c. Higher industrial and economic levels

d. Correction of international imbalances

e. Pioneering of new frontiers of space and oceans

<2> Trends in Levels of Japanese Industrial Research and Technology, Trends at Leading Edge of Industrial Technological R&D

<3> Japan's Identity, With Adequate Consideration Given to Changes in Internal and External Environment Surrounding Technology

(B) In tackling the high-priority R&D tasks,it will be necessary to be flexible, according to the nature of each task and the extent to which it has already been researched and developed. This also applies to applications and developmental aspects. Fundamentally, however, the priorities must be placed on original and basic fields. In tackling the R&D tasks which involve the resolution of global problems, moreover, the following factors must be considered.

<1> The fact that the problems pose a basic threat to the survival of the human race, therefore demanding resolution or improvement as quickly as possible, for the sake of humanity

<2> The fact that energy- and environment-related problems are interrelated, making it necessary to elucidate the mechanisms of such interrelatedness in order to develop radical solutions and attack the problems at their source

These problems must be attacked from a wide base of operations that comprehends everything from the marshalling of existing technologies for immediate holding actions to the carrying on of research and development in more basic and fundamental areas.

(C) In Figure 3-2-2 are represented some of the R&D tasks that accord with this perspective. Such research and development will, of course, bring about certain secondary effects, including the following:

<1> Elucidation of mechanism of high-temperature superconductivity. This is key to the development of high-temperature superconductor materials. The development of high-temperature superconductor materials and devices will have spin-off effects in a wide range of fields, including a) energy fields such as nuclear fusion and electric generators, b) MRI and other medical equipment fields, c) SQUID and other measurement fields, d) Josephson elements, high-speed LSI wiring, and other data processing fields, and e) the transportation field, including the linear motor car and electromagnetic ship propulsion.

<2> Elucidation of various organic functions and mechanisms. This is essential to the research being done on the use of organic membranes, the sophisticated utilization of intra-organism reactions, and the development

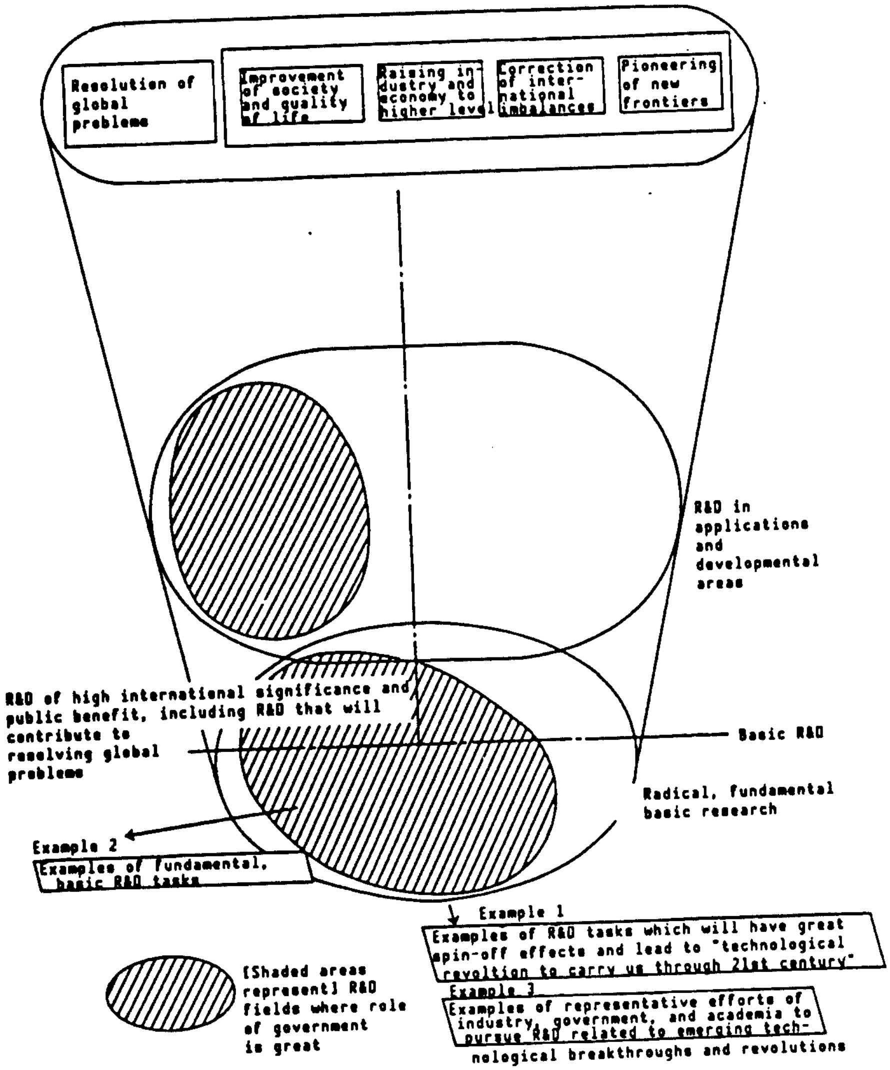


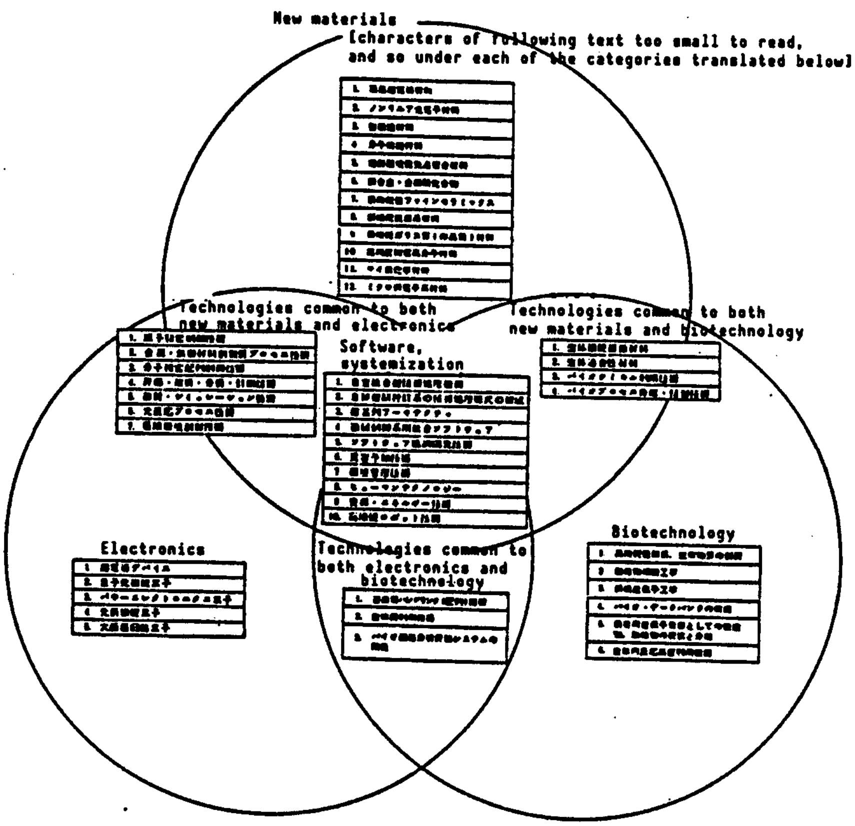
Figure 3-2-2 Priority Fields for "Technological Revolution To Carry Us Through 21st Century"

Source: Agency of Industrial Science and Technology

[figure continued]

[Continuation of Figure 3-2-2]

Example 1: Examples of R&D tasks which will have great spin-off effects and lead to the "technological revolution to carry us through the 21st century"



Example 2: Examples of fundamental, basic R&D tasks

a) Elucidation of mechanism of high-temperature superconductivity
b) Elucidation of various organic functions and mechanisms
c) Elucidation of cerebral information processing mechanism
d) Development of techniques for precision control of atomic and molecular structures

Source: Agency of Industrial Science and Technology

[figure continued]

[Continuation of Figure 3-2-2]

Example 3: Examples in representative efforts of industry, government, and academia to pursue R&D related to emerging technological breakthroughs and revolutions

High-temperature Superconductor Materials

Universities Pursuit of truth	National laboratories Create new technologies	Private industry Apply, develop new technology
Theoretical elucidation of high-temperature superconductivity (pursue new theories to replace BCS theory), etc.	Search for and systemize new high-temperature superconductor materials etc.	Research process characteristics of new high-temperature superconductor materials (make into [marketable] materials, etc.

Energy Conversion Mechanisms That Use Organic Functions

Universities	National laboratories	Private industry
Theoretical elucidation of how constituent proteins in molecular aggregates in energy conversion systems are interaligned, etc.	Elucidation of correlation between roles, structures and functions of constituents in molecular aggregates in energy conversion systems, etc.	Research techniques for controlling protein molecule arrangement to alter and reconfigure molecular aggregates etc.

Neurocomputer, Fuzzy Information Processing

Universities	National laboratories	Private industry
Exploration, formulation of new theories to replace von Neumann data processing, etc.	Design of computer concepts based on the new theory, etc.	Research new elements required to implement new computer concepts, etc.

Notes:
1. The examples noted above were selected from among various examples of research being done by industry, government, and the universities so as to indicate representative efforts in which the peculiarities of each division are clearly evident.
2. The national laboratories alluded to above are testing laboratories that are under the aegis of the Agency of Industrial Science and Technology.

of materials that imitate organic functions. By developing techniques for artificially applying or reproducing the elucidated functions and mechanisms, it will become possible to apply the multi-level chemical reactions conducted in living organisms and the highly precise selection mechanisms of organic substances to industrial production processes. When this happens, a) the chemical industry will be able to achieve phenomenal growth, b) it will become possible to sense and control the substances which contribute to intra-organism reactions (very promising in terms of medical applications), and c) man will be able to participate in the material cycle within the ecosphere. These achievements should give us clues as to how to solve the environmental problems that have now grown to global proportions.

<3> Elucidation of cerebral information processing mechanism. Besides facilitating pattern processing, inference-making, and ambiguous ("fuzzy") information processing (which the conventional von Neumann computer handles so ineptly), this will make it possible for the computer itself to learn. The improved harmony between man and machine which this brings about, and the resulting advances in intelligent, flexible information processing, communications, and control equipment, will contribute greatly to the creation of a truly high-level information society.

<4> Development of techniques for precision control of atomic and molecular structures. This is essential to the research being done on nonlinear photoelectronic materials and new-function optical elements. The successful development of these technologies will pave the way for super-multiplexed optical communications, environmental measurement and monitoring on a global scale, and sophisticated remote sensing technology. Also benefiting will be the research now being done on the optical computer, the advent of which will have a major impact, not only in such fields as information, aerospace, and medicine, but also on culture and daily life.

Section 3. Creating Comprehensive Industrial Technological Development Program for "Technological Revolution To Carry Us Through the 21st Century"

1. Fundamental Policy

In Japan, both the government and private industry have forged ahead aggressively with research and development. Meeting the challenge of the "technological revolution to carry us through the 21st century" and making active international contributions, however, entails basic research that is highly original and radical. Accordingly, there are limits to how much can be done by private industry, and the government must play a large role. We think that thoroughgoing efforts are needed in order to achieve the levels of government-based R&D funding necessary to ensure that Japan fulfills its rightful role. (Cf Notes below) Our research programs and results must also be open to international interests.

In addition, we must provide the programs and research environments necessary and suitable for basic, creative research.

2. Priority Tasks

In forging ahead with industrial research and development, we need to strengthen our efforts in areas of basic and creative research and to engage even more actively in making international contributions, while clearly recognizing the turning point which we have reached. To do this will require that we set the priorities noted below and recreate the overall fabric of our industrial technological R&D.

Notes:
1. GNP percentages of government R&D expenditures among advanced nations (FY 1985): Japan 0.58 percent, United States 1.27 percent, England 0.99 percent, France 1.25 percent, West Germany 1.12 percent.
2. Japan's Selective Research Society [Sentaku Kenkyukai] recommended in "Japan's Choices," published in May 1988, that Japan try to raise government R&D funding above 1 percent of GNP. It is similarly suggested in "Trade Policy Outlook for 1980's" (March 1980) that government R&D expenditure be raised to about 1 percent of GNP by the late 1980's (targeting a total government R&D expenditure-to-GNP ratio of 3 percent, with government bearing at least 40 percent or so of the R&D burden).

(1) Beefing Up Japan's Basic Research

(A) Government's Role

<1> In undertaking basic, creative research, the government must first recognize the increasingly important role played by the national testing laboratories, particularly in such areas as

<a> radical and fundamental R&D that is high-risk in nature but from which a chain of spin-off benefits can be realized, and

<b> R&D of a highly public or international nature which will contribute to the resolution of global problems.

Recognizing these facts, the government needs to work out its own R&D policies more fully and begin to play a more autonomous role.

<2> In order to encourage basic research in the private sector, moreover, it is important that efforts be made to

<a> educate and train research personnel (developing research leaders capable of carrying on independent research, producing research personnel trained in the recent currents of industrial technology, retaining more research assistants, and providing other needed research support),

<b> firm up the research support infrastructure (providing large-scale experimental research facilities, improving databases, supplying standard substances, improving test and evaluation systems, and promoting research industries),

<c> provide programs to promote closer cooperation between industry, academia, and government, and

<d> provide opportunities for technological exchange.

<3> At the same time that it is strengthening its hand in research and development, the government must do more studies on the problems associated with the interaction between technology, on the one hand, and society and culture, on the other, realizing that technology has now become an even stronger driving force behind social and economic development.

(B) Role of Private Industry

<1> Changes are also being mandated in private industry, where societal and economic demands are becoming more sophisticated and, more than ever before, it has become necessary to make products more highly functional and with higher value added. For these reasons, it is becoming necessary for companies to have an abundance of basic technology at their disposal. Some basic research that was formerly undertaken at national testing laboratories is now being viewed seriously and undertaken by industrial researchers.

<2> There are limits to how much basic research can be undertaken by private industry. Nevertheless, private companies must now orient their R&D activities more toward basic research fields than previously, recognizing the two major tasks in the area of industrial technology that now face Japan at this turning point in our industrial history.

(2) Intensified Promotion of International Exchange and Cooperation

(A) Role of Government

<1> In taking up the challenge of the "technological revolution to carry us through the 21st century," the interaction between forefront experience and diverse concepts is becoming more important than ever before.

<2> As noted earlier, the government must use the experience and successes gained from taking on this challenge, as well as the spin-off effects resulting therefrom, to the best possible advantage in making more significant contributions to the international community. Recognizing this, the government must also promote the effective utilization of R&D resources and the efficient and effective conduct of R&D activity. In order to do this, the government needs to take the lead in

<a> sponsoring international joint research projects, and cooperating in projects promoted by other nations, particularly when those projects pertain to fundamental technologies common to the human race, an example of which is seen in the Human Frontier Science Program.

<b> participating even more actively with other nations in seeking to resolve global problems, particularly global environmental problems,

<c> vigorously promoting industrial cooperation and the transfer of Japanese experience as related to the transfer of the results of scientific and industrial R&D to industrial fields,

<d> instituting and developing research programs that are open to other nations,

<e> providing high-level facilities for joint research that will be highly regarded internationally, and

<f> playing a larger role in international efforts to achieve standardization.

<g> Also, in view of the fact that the role of science and technology is extremely important in promoting independent growth in the developing nations, Japan needs not only to engage in transfers of its outstanding production technology to these countries, but also to help train their research personnel, cooperate in other ways to strengthen their R&D infrastructures, and promote joint R&D operations in fields where the need is greatest. In addition, Japan must build cooperative relationships and create opportunities for active exchanges in industrial technological areas with the rapidly developing NIEs.

(B) Role of Private Industry

In the private sector also, as markets have become progressively internationalized and demand has become more and more sophisticated, industrial R&D objectives have become more creative and basic. In the interest of supplementing R&D resources and scientific knowledge, and seeking greater mutual enlightenment, there is therefore a growing need to expand the volume of international information exchange. The effective transfer of technology overseas is also important in the context of developing greater business opportunities overseas.

In making even more strenuous efforts in these areas, private industry will benefit itself in a significant way because it will thereby be expanding its own base for future growth.

- END -